FRONTISPIECE.

A

TREATISE

OF

ARTILLERY:

CONTAINING,

I. General Constructions of Brass and Iron GUNS used by Sea and Land, and their CARRIAGES.

II. General Constructions of MORTARS and HOWITZES, their BEDS and CARRIAGES.

III. DIMENSIONS of all CARRIAGES used in ARTILLERY.

IV. EXERCISE of the REGIMENT at Home, and SERVICE Abroad in a SIEGE or BATTLE.

V. Its MARCH and ENCAMPMENT, AMMUNITION, STORES, and HORSES.

VI. Lastly, The necessary LABORATORY WORK for FIRE-SHIPS, &c.

To which is prefixed,

An INTRODUCTION,

WITH

A THEORY of POWDER applied to FIRE-ARMS.

9573

The THIRD EDITION,

With large Additions, Alterations, and Corrections.

By JOHN MULLER,

Professor of ARTILLERY and FORTIFICATION,

And Preceptor of Engineering, &c. to his Royal Highness the DUKE of GLOUCESTER.

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Where may be had, MULLER'S Mathematics, Fortification, Attack and Defence, Field-Engineering, &c. 8 Vols.

TO

HIS ROYAL HIGHNESS

The Duke of GLOUCESTER, &c.

THIS WORK

Is moſt humbly Dedicated,

BY

His Royal Highneſs's

Moſt devoted,

Moſt obliged, and

Moſt obedient Servant,

JOHN MULLER.

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INTRO-

INTRODUCTION.

THE origin of fire arms and artillery is owing to the diſcovery of gun-powder; but when this was, or in what country, we are ignorant of: it is however probable, that it muſt have been in the eaſtern part of the world, becauſe ſaltpetre, which is the principal ingredient, is found in great plenty in ſome provinces on the ſurface of the earth, and from thence is brought to *Europe* ever ſince its uſe has been known; and ſaltpetre being mixed with ſulphur, or ſome other combuſtible ſubſtance, either by chance or otherwiſe, produced a power by its exploſion not known before, whereby bodies could be thrown to a great diſtance.

It is generally ſuppoſed that the *Chineſe* were the firſt that made this diſcovery; for *Uſano Valeſco*, a *Spaniſh* author, mentions, that powder and guns were found in *China* in the year 85, by king *Vitey*; but whether it was known before in any other country is uncertain.

The firſt diſcovery of powder in Europe was made by *Bartold Schwartz*, a Monk, at *Mentz*, in 1320, by accident; being a chymiſt, he happened to mix ſome ſaltpetre with ſulphur in a mortar, and covered it with a ſtone; the compoſition accidentally taking fire, the exploſion blew the ſtone to a conſiderable diſtance. This ſuggeſted the notion, that if this compoſition was properly confined, it might be uſeful in the attack and defence of places: and from thence the invention of guns may be dated in *Europe*.

Roger

Roger Bacon, who lived about 50 years before, mentions a compoſition known in his time, by which thunder and lightning could be imitated: *Schwartz* was the firſt who applied it to military uſes.

It is ſaid that the *Venetians* made the firſt uſe of guns at the ſiege of *Claudia Jeſſa*, now called *Chioggia*, in 1366, which were brought there by two *Germans*, with ſome powder and leaden balls; but father *Daniel* proves from records, that the *French* had guns in 1338. As the invention of guns is ſo immediately connected with that of powder, it could not well be otherwiſe than that *Schwartz* was the inventor of both; and that they were from thence carried to *France*, and afterwards to *Italy*.

Some authors ſay, that the firſt guns were made of iron bars laid lengthways, and kept together with ſtrong iron hoops; and others, with thin ſheets of iron rolled up together and hooped; but which way they were made, it muſt have been in a rude and imperfect manner, like the firſt eſſays of many new inventions.

The firſt guns were but ſmall, and their ſhot of lead; but afterwards, when their uſe became better known, they were caſt of gun metal, and of extraordinary ſize; and their ſhot were made of ſtone: for the *Turks* had ſome at the ſiege of *Conſtantinople*, that threw a weight of 500 lb. and *Louis* XI. had one caſt of the ſame ſize; many others are mentioned in hiſtory, which carried ſhots that weighed from 80, 90, to 100 pounds.

But as theſe guns were ſo very heavy, and could not be tranſported without great difficulty, they have been reduced to ſmaller calibers, and made their ſhot of iron. Since that time the largeſt caliber that were uſed was a 48 pounder; but at preſent no larger are made in the land ſervice than 24; and at ſea 42 pounders.

It was long imagined, that the more powder a cannon was loaded with, the greater its execution would be; for which reaſon they were loaded with as much powder as their

their ſhot weighed, and to reſiſt ſo great a force, they were made very heavy, and of a great length, in order to give time to the powder to burn all before the ſhot left the piece.

This great charge was diminiſhed afterwards to two thirds, and then to one half, without leſſening the weight of the guns, or their length. The chevalier *Belidor* made ſome years ago ſeveral experiments relating to the charge of battering pieces, whereby he found that one third of the weight of the ſhot was ſufficient, and the *French* uſed no more during the two laſt wars: it is very probable that leſs might do; for ſome experiments were made at *Woolwich* with light field pieces, and it was found that one fourth and even one fifth was ſufficient for the charge of theſe pieces.

Notwithſtanding the great importance it would be to a nation to have its artillery carried to ſuch perfection, as to make uſe of as little metal and workmanſhip as poſſible, and at the ſame time to bring as many and as large calibers into the field as others, thereby reducing its immenſe expence to as little as is abſolutely neceſſary; yet it will be found upon examination, that very little improvement has been made in the proportions of guns ſince *Dilichius*, a *German*, who wrote near 200 years ago.

It is true *St. Remy*, a *French* author, publiſhed in 1723 the moſt compleat and extenſive Treatiſe of Artillery, in two volumes in quarto, that is extant; which has ſince been much improved in the laſt *Paris* edition, in three volumes, publiſhed in 1745, containing all the improvements made in the artillery ſince the firſt edition: but as it is only a collection of memoirs he received from the different artificers employed in theſe works, and who had no other knowledge than bare imitation, it could therefore not be expected that what they tranſmitted to him was grounded upon ſuch mechanical principles as depended upon mathematics, without which no real improvements can be made.

All

All the authors that wrote ſince have done no more than copied his works in an imperfect manner, even the *German* authors follow him; though it is plain that the *French* have chiefly copied *Dilichius*: for their field carriages are exactly the ſame to this day as he has delineated them in his work; and as to the alterations they have made in the proportions of guns, they are trifling and very little to the purpoſe.

If we conſider the various lengths and weights that have been given to pieces of artillery at different times by all nations, it will appear, that no principle is ſo uncertain and unſettled as that upon which the artillery artificers have grounded their conſtructions. For in queen *Elizabeth*'s time they made ſome 18 pounders 24 feet long, caſcable included, ſuch as the culverin in *Dover Caſtle*, and that at *Nancy*; and in king *Charles* the ſecond's, Count *Mansfield* made ſome 6 pounders that weighed but 180 lb. and 25 pounders of 700 lb. as is related in the account of the ſiege of *Breda* by the *Spaniards* under the command of *Spinola*; and about the ſame time the *Spaniards* caſt ſome others not much heavier; one of them we had at *Woolwich* was 7 feet long, weighed only 21 : 3 : 4, and carried a ſhot of about 41 pounds of our weight.

Though theſe light pieces were then highly eſteemed for their eaſy carriage and facility of working, yet much heavier and longer have been made ever ſince without any manner of reaſon, till 1744, when Colonel *Weideman*, a *German*, brought light pieces in uſe again as a new invention of his own. His pieces were made of ſheets of copper rolled up and ſoldered together; they were ſo very light, that a 6 pounder weighed no more than two hundred and a half, and yet ſtood all the proofs that were required.

This gave riſe to our light field pieces; but it was not without great difficulty that they were received, and no leſs than the expreſs command of his royal highneſs the late duke of *Cumberland*, could have prevailed over the

the servile attachment for an old established custom though ever so erroneous, which, when once covered by the veil of time, becomes in a manner sacred.

But even lighter field pieces than the present might be used; for on the 12th of *June* 1751, some experiments were made on *Putney-Common* by baron *Stark*, a *German*, with a piece made of a new metal of his invention; which piece was a 6 pounder of 3 feet and a half long, and weighed 3 : 2 : 0, as he said, and it was fired 300 rounds in three hours and 45 minutes, being loaded each time with a pound and a quarter of powder, without receiving the least damage.

This trial being reported to lord *Ligonier*, then master general of the ordnance, he and the rest of the principal officers of the board resolved to try our light 6 pounders, in order to know whether they would stand the same trial or not; and accordingly, on the 15th of *June*, my lord pitched upon one amongst those that had been used at the battle of *Lafeldt*. This piece was four feet and a half long, and weighed 4 : 3 : 0; and after being fired 300 rounds in three hours and 27 minutes, loaded with the same charge as that above, was found not to have received the least damage. The same trial has been repeated afterwards with a gun of the same dimensions as the former, which had been made by another founder, and it succeeded as well.

These trials shew, that those light pieces are sufficiently strong for any action ever so obstinate; and that pieces in general may be made lighter than they are at present, appears from several other trials made since with light brass pieces, according to my construction, as will be shewn hereafter.

It is said that such light pieces would not do for battering breaches, nor on board of ships, because of their recoiling too much; but it should be considered, that batteries made upon these occasions are always, or ought to be near the object, and the charges now used are but half the former, because a shot, which has a sufficient

velocity

velocity just to enter the wall, shakes it more and destroys it sooner than if the velocity was much greater. This is a matter of fact grounded upon experience.

It is supposed at present, that no less caliber than a 24 pounder will do to make a breach; and it may so happen, that the heavy pieces cannot be carried through bad roads, as in *America*, or over high hills, as in *Scotland*. Upon these occasions it seems to be absolutely necessary to have light pieces: for which reason we have given a new construction of light pieces in page 62, where the weight of a 24 pounder is 18 : 1 : 5; which differs in some things from those used at present: because mine are made the same number of calibers long, and their weights in proportion to that of their shot, as we shall prove hereafter they should be; whereas the large calibers of the present are made shorter and lighter in proportion than the small; and it has been found by experience, that the present light 24 pounders recoil too much, let the hind part of the platform be ever so much raised.

Artillery has hitherto been considered merely as practical, without conceiving that for want of the mechanical principles deduced from mathematics, no improvements can possibly be made. For all the experience of the artillery officers cannot be of any use in the construction of pieces, as their business is to make the best use of them, and not how they are made, neither are they ever consulted upon that subject.

To put the artillery upon a better footing than it has hitherto been, proper experiments should be made in time of peace, and by such as have sufficient knowledge, so as to be able to draw just inferences, which is seldom the case, as it appears by those hitherto made, and which will be inserted hereafter, where it will be shewn how little the most of them may be relied on.

It is certain, that in most cases common geometry and the principles of mechanics is sufficient; but there are others which cannot be determined without the higher

principles

principles of mathematics. For how can the velocities of ſhots and ſhells be determined without being acquainted with the laws of reſiſtance, and which cannot be known without the uſe of fluxions, nor the finding the curve deſcribed by the ſhot, which is one of the moſt intricate caſes? Again, the proper length and charges of pieces cannot be determined without the laws of motion in a reſiſting medium: it is true that experiments may be made for that purpoſe; but how far we may depend on them, without being confirmed by a proper theory, will appear hereafter.

A remarkable cuſtom has prevailed all over *Europe*, which is the making ſmaller calibers much longer in proportion than thoſe of a higher nature; imagining, I ſuppoſe, to increaſe thereby the velocity of the ſhot, without knowing that a piece may as well be too long as too ſhort; as long as this pernicious cuſtom prevails, no improvement can be made in artillery; for as a greater number of ſmall calibers are uſed than large, and the ſmall are thereby as heavy again as they need be, were their length of a juſt proportion.

Had it been known that every caliber has but one determined length and charge by which it will carry its ſhot farther than any other greater or leſs, and that it cannot exceed a determined velocity, let the ſhot be impelled by any force whatever, and that theſe velocities are always in proportion to the diameters of the ſhot, this practice would not have been followed. But as the demonſtrations of theſe principles depend on the method of fluxions, which would not have ſo well ſuited in a practical treatiſe as this, I was obliged to write a treatiſe, where every thing relating to artillery, not inſerted here, will be found.

To ſettle artillery upon a proper foundation, we ſhall relate all the moſt remarkable experiments made here and abroad, beginning with thoſe inſerted in *St. Remy*'s memoirs, volume i. page 114, which are ſaid to be the oldeſt upon record.

It is easily perceived, that no dependance can be had on these experiments. For it is a plain contradiction, that the point blank ranges of a 24 and 16 pounder should be longer than that of the 33 pounder; and that the random range of these last guns should be no more than that of the 24 pounder. Again, the 16 pounder random range to be so much greater than the rest.

Ranges in Paces.

Calib.	Point blank.	At random.
33	600	6000
24	800	6000
16	800	8000
12	450	5000
8	300	3000
4	150	1500

As neither the length and weight of pieces, nor the weight of the charges are mentioned, though the experiments were true, no useful inferences can be drawn from them.

Monsieur *du Metz*, lieutenant general, made in his time the following experiments on the ranges of guns, by which he found that the *French* pieces loaded with two thirds the weight of the shot, and those of the new invention loaded with one third, ranged the same distances when elevated at an angle of 45 degrees.

Calib	Ranges.
24	2250 Toises
16	2020
12	1870
8	1660
4	1520

As neither the length or the weight of the pieces are mentioned, nothing can be concluded from these experiments. It is surprising that *St. Remy* did not mark the dates of these experiments, nor what the *French* pieces were at that time, as well as those of the new invention. If I may venture to guess, their length were 10 feet, all except the 8 and 4 pounders, which were only 8 feet, according to the second table hereafter; and those that are called of the new invention had spherical chambers.

If

If this be true, all that can be concluded is, that 10 feet is a better length for a 24 pounder than for any other caliber, when loaded with a weight of powder equal to the two thirds of their shot; but as no piece is loaded at present with that charge, these experiments can be of no use.

There are several tables of the lengths and weights of the *French* pieces used at different times not specified, except the last of the present.

That which seems the oldest is the following, pag. 73, volume i.

This table shews how rude and imperfect the first trials of artillery were, and what enormous length the smaller calibers were made in those times.

It is also to be observed, that the 24 pounder, tho' 13 feet long, weighed no more than 4300 lb. whereas the present of 10 feet weigh 5400 lb. If the former were found to be sufficiently strong, what could induce them to load them with so much metal now? All that can be said is, that if experiments are made for a particular fancy only, and are not enquired into by the successors, all the attempts an author can make for improvement are vain and useless to the public.

TABLE I.

Calib.	Length.	Weight.
	Feet Inch.	
48	10 : 0	7200lb.
40	16 : 6	7000
32	22 : 0	7200
24	13 : 0	4300
20	16 : 0	7000
16	18 : 0	4200
12	11 : 0	4250
10	13 : 0	3850
8	15 : 0	3500
4	12 : 6	2100

In the table facing page 207, vol. ii. are marked the following dimensions,

This table shews that the length and weight of pieces were better proportioned in that time than they were before: but that the length of the 24 and 16 pounders should be the same as that of the 33; as likewise the 8 and 4 to be of the same length, shews the little reasoning made use of in that time.

TABLE II.

Calib	Length.	Weight.
33	10 : 0	6200lb
24	10 : 0	5100
16	10 : 0	4100
12	10 : 0	3400
8	8 : 0	1950
4	8 : 0	1300

The last regulations that were made in 1732, and which are followed at present, may be seen in the next table. It is evident, that the lengths and weights were not deduced from any solid reason, but from the fancy of those who are most at the head of that branch.

That the weight of these guns is greater than they need be, appears from our iron 24 pounders weighing no more than 4800, which is even too much, as will be shewn hereafter; and according to this proportion, the set of them contains 3250 lb. of metal more than the strongest construction requires.

TABLE III.

Calib.	Length.	Weight.
24	10 : 1. 5	5400lb.
16	9 : 6	4200
12	9 : 0	3200
8	8 : 1	2100
4	6 : 9	1150

It must be observed, that the *French* reckon by the neat weight, and not by 112 pounds for a hundred weight, as we do; but it is shewn in page 11, that 100 *French* pounds weigh something more than 114 of our

our pounds; ſo that a *French* hundred neat weight is more than our hundred of 112 pounds.

We ſhall now come to the experiments made at home, or under the direction of *Engliſh* officers. The firſt on record that came to my knowledge are thoſe made by general *Armſtrong*, ſurveyor-general, in 1736, which are:

The length of theſe pieces are expreſſed in feet and inches, and the ranges in yards: out of a great many trials, three of the longeſt ranges of each piece are ſet down here. All theſe pieces were braſs 24 pounders, and all weighed nearly 5200, and were always loaded with two thirds of the ſhot's weight, that is, with 16 pounds.

Length.	Range.	Range	Range.
10 : 6	2486	2614	2406
10 : 0	2570	2532	2436
9 : 6	2633	2560	2500
9 : 0	2796	2494	2563
8 : 6	2586	2490	2466
8 : 0	2438	2470	2453

The intent of theſe experiments was to find the beſt length for a battering piece, when loaded with the common charge then given; and that of 9 feet 6 inches was fixed upon as the beſt, though the firſt and laſt of the 9 feet ranges were the longeſt of thoſe in the ſame columns: this was owing, I ſuppoſe, to this length being more convenient for battering than that of 9 feet long.

If we examine ſtrictly into theſe experiments, it will be found, that no improvement can be made from them. For no two guns can be equally bored, and the leaſt difference may cauſe a conſiderable one in the ranges: nor no two vents can be pierced ſo as to come out at the ſame diſtance from the bottom of the bore, which is of the greateſt conſequence, as we ſhall prove from repeated experiments.

Length.	Number.	Elevation.	Ranges in Yards.	Powder
11 Feet.	1	6 Degrees.	1780	9 Pounds of Powder.
	2		1750	
	3		1725	
	4		1725	
9 Feet.	5		2000	
	6		1830	
	7		1965	
	8		2018	
11 Feet.	9	7¼ Degrees.	1860	
	10		1935	
	11		1960	
	12		2048	
9 Feet.	13		2060	
	14		2165	
	15		2050	
	16		2272	
11 Feet.	17	10 Degrees.	2490	
	18		2395	
	19		2567	
	20		2670	
9 Feet.	21		2910	
	22		2780	
	23		2790	
	24		2577	
11 Feet.	25	12 Degrees.	3016	
	26		2720	
	27		2800	
	28		3000	
9 Feet.	29		2712	
	30		2910	
	31		2955	
	32		3070	
11 Feet.	33	15 Degrees.	3185	9 Pounds of Powder.
	34		30[illegible]5	
	35		3400	
	36		3[illegible]85	
9 Feet.	37		3532	
	38		2940	
	39		3460	
	40		3725	
11 Feet.	41	10 Degrees.	2550	
	42		2377	10lb.
	43		2365	
	44		2575	
	45		2405	11lb.
	46		2375	
	47		2520	
	48		2605	12lb.
	49		2645	
	50		2730	10lb.
	51		2380	
	52		2445	
	53		2200	11lb.
	54		2780	
	55		2550	12lb.
9 Feet.	56	45 Degrees.	4160	9 Pounds.
	57		4135	
	58		4100	
	59		3970	
	60		4015	
	61		3980	
	62		3700	
	63		3960	10lb.
	64		3945	
	65		3785	11lb.
	66		3930	
	67		3802	12lb.

But

But ſuppoſing all the pieces were exactly bored alike, and the vents placed the ſame, what other concluſion could be drawn from theſe experiments, than that the beſt length of a 24 pounder is 9 feet 6 inches when loaded with 16 pounds of powder? It is not probable, that if a leſs charge was uſed, as at preſent is the caſe, this length would be the beſt; neither can we draw any inferences from them in reſpect to the length of greater or ſmaller calibers.

It is not ſufficient to make experiments without any intention of their being uſeful towards the improvement of artillery in general, and ſuch as proper concluſions may be drawn from them; otherwiſe the greateſt uſe they can be of, is to determine ſome particular caſes only, which are by no means ſufficient.

The beſt and moſt uſeful experiments that have hitherto been made, are thoſe of general *Williamſon*'s, aſſiſted by major *Hiſlope*, and ſeveral other officers of artillery, which I ſhall inſert here, as taken from major *Hiſlope*'s account.

Experiments made at *Mahon* in *Minorca* in 1745, with two iron 18 pounders, one of 11 feet long, which weighed 51 : 0 : 5; and the other of 9 feet weighed 39 : 1 : 3. They were fixed upon a rocky ground, and ſo contrived as to be elevated to any number of degrees.

Hence it appears, that when the pieces were loaded with 9 pounds of powder, the range was greater than when loaded with more or leſs.

Again, that the pieces of 9 feet long carried farther than thoſe of 11, in almoſt all the ſame circumſtances, though the firſt is lighter than the ſecond; which ſhews that the length of the ranges does not ſo much depend on the weight, as on a proper length, and on a proper charge.

The accuracy of theſe experiments is confirmed by the theory; for we have proved in our appendix, that the greateſt range an 18 pounder can have, when elevated to 45 degrees, cannot be quite equal to 4190

 yards,

yards, becauſe we have ſuppoſed ſuch a velocity as the ſhot cannot poſſibly have, but may continually approach it.

Now as the greateſt range in theſe experiments is 4160 yards, which differing only by 30 yards, the computed ones evidently prove the accuracy of theſe experiments; and it proves with no leſs certainty, that 9 pounds of powder communicated the greateſt velocity to the ſhot that it poſſibly could receive by any force whatever.

When thus experiments agree with a theory founded upon unexceptionable principles, there cannot remain the leaſt doubt of their certainty.

As 9 feet is nearly 21 diameter of an 18 pounder ſhot, and 9 pounds of powder half the weight of the ſhot; and it is preſumed that pieces, whoſe lengths and charges are proportional, will have their ranges likewiſe ſo; becauſe their greateſt velocities are proportional to the diameters of the ſhot, as we ſhall prove in the appendix: we may conclude with ſome degree of certainty, that if the length of a piece of any caliber be 21 diameters of its ſhot, and loaded with powder equal to half the weight of the ſhot, it will carry farther than any other of the ſame caliber. either longer or ſhorter, loaded with any charge whatever.

Thus we have at laſt determined that important queſtion in artillery ſought for ever ſince its invention; but to be entirely convinced of the truth of our determination, more experiments of this kind ſhould be made with various calibers; but care ſhould be taken that they may not be liable to any exception.

The moſt certain way of proceeding, in my opinion, would be, to caſt a gun of any caliber of 22 diameters of its ſhot long; to examine whether it is truly bored, and that the vent comes exactly out at the bottom of the bore; then let it be fired with various charges and elevations, till there is a ſufficient proof of its beſt charge; this being done, a part of the piece muſt be ſawed off the length of its diameter, and the firſt trials repeated

repeated as before: and when the beſt charge and its range are aſcertained, the length of the piece muſt be diminiſhed again by the length of the diameter of its ſhot. Theſe trials being continued till the greateſt ranges diminiſhes, then the beſt length and charge will be aſcertained of that caliber; and thoſe of any other caliber may be found in the ſame manner. The only care to be taken in theſe experiments, is to mix well the powder, and to dry it in the ſun, that it may have always the ſame ſtrength as nearly as poſſible: another caution muſt be taken, which is, to make theſe experiments in clear and ſerene weather, and of the ſame heat, becauſe the powder will act more violently in a cold froſty morning than in hot weather, as ye ſhall ſhew.

Though it is proper to know the beſt length and charge of a piece, yet in real ſervice their length depends moſtly on the uſe they are made of, according to the different circumſtances: thus ſhip guns ſhould be ſhort and light, ſo as to be eaſily houſed and loaded, becauſe the rammer handle is made of rope; in long pieces it muſt be bent, which requires great care to ram the powder and ſhot home; and when this is not done, the priming fires without the powder, which is always in cartridges; the ſailors thinking that the ſhot was diſcharged, load it again, and miſs firing as before. This has been found ſo for three times running, and when at laſt the powder in the firſt cartridge takes fire, often burſts the gun, and deſtroys the ſailors placed near to ſerve it; whereas when the guns are ſhort, the rammer handles may be made of wood in all ſmall calibers, and the ſervice become more expeditious. Beſides, ſhips now come ſo near to one another, that the ſhots are not required to go ſo far; provided it takes place it is ſufficient.

The only objection againſt light guns is, that if they recoil too much, they will be apt to tear their tackle; but it has been found by experience, that half the uſual charge is quite ſufficient, and perhaps leſs. If then the charge is diminiſhed, the weight of the gun may like-

wiſe be diminiſhed, without increaſing the recoil. This ſhould however be done with diſcretion, and not without proper trials; for hazards ſhould be avoided as much as poſſible.

Field pieces or battalion guns ſhould be ſhort and light, in order to be able to advance or retreat as faſt as the army; ſuch are thoſe we make uſe of at preſent, with very little alterations in the calibers above a 6 pounder.

Battering pieces, on the contrary, ſhould be of a proper length to enter into the embraſures, that by their blaſts they may not deſtroy them too ſoon, becauſe it cannot be prevented entirely; for which reaſon the gunners repair them every evening when it is dark.

With regard to garriſon pieces, their length ſhould be ſuch as that the ſhot may go fartheſt, becauſe in a ſiege they will oblige the beſiegers to open their trenches at a greater diſtance, which is generally without gun ſhot; and in a fort placed near a navigable river, or the ſea, they will reach the ſhips, when the ſhips cannot reach the fort.

For theſe reaſons we make in our new conſtructions the length of light field pieces 14 diameters of their ſhot, the ſhip guns 15 of thoſe diameters, and the battering as well as the garriſon pieces 21; whereby the 24 pounder for battering becomes 9 feet 8 inches long; which is 2 inches more than the uſual length. We might likewiſe uſe a 32 pounder, which, according to our conſtruction, page 52, would weigh but 5400, that is, only 200 more than our preſent braſs 24 pounder.

The intent of the following experiments, which I made in 1753 with two ſmall mortars, was to find the propereſt place of the vent, and the beſt figure of the chambers: their bore was three inches, and 7.5 long; one had a cylindric chamber of one inch diameter, and two long; the other a concave in the ſhape of an egg, with a ſmall cylindric entrance of half an inch diameter, and the inſide terminated by a ſharp edge. Both theſe chambers held an ounce of powder at firſt, but widened

by

by firing so as to hold an ounce and a quarter afterwards. Each had two vents, one in the middle, and the other at the bottom; I had a screw to stop one when the other was used: the mortars weighed 36 pounds each, and the shells 2 pounds 7 ounces at a medium. We have not marked the angles of elevations, because they were unnecessary, only so far as that they were the same, when the lower and upper vents were compared.

Pdr.	Vent	Cylind.	Concave	
One Ounce.	Middle	650	750	Loaded with the common shooting powder. Weather cool in the morning, and sultry afterwards.
		630	730	
		600	686	
		550	722	
		560		
	Lower.	806		
		900		
	Middle	800	889	With common ordnance powder. Weather warm and windy.
		756	875	
		864	877	
1¼ Ounces.	Lower.	1100	1194	With the best ordnance powder. Weather warm and windy.
		1023	1088	
		1003	1121	
		1020	1122	
		1020	1200	
		Ranges in Yards.	Ranges in Yards.	

Colonel *Desaguliers* and myself made several other experiments, together with a mortar of the same size that had several shifting chambers. The substance of what was most remarkable in them are as follows:

A narrow cylindric chamber of about four inches long holding 12 grains of powder, being loaded with 6 grains by means of a thin cartridge: when the powder was placed close to the shell, so as the lower part of the chamber

chamber was empty, and fired by means of a quick match introduced through the vent; and after this, it was loaded again with the ſame charge placed at the bottom of the chamber, and the empty ſpace between the ſhell and the powder; the ſhell went near twice the diſtance in the firſt experiment that it did in the ſecond, and when the powder was placed in the middle of the chamber at an equal diſtance from the bottom and the ſhell, the diſtance or range was a mean between the two former. Theſe experiments were frequently repeated, and the ranges in the firſt caſe were always nearly double thoſe in the ſecond. From what cauſe it may proceed that the ſame quantity of powder, placed in the ſame ſpace, ſhould produce ſuch various effects, is not in my power to conjecture.

The ſame mortar being loaded with the ſame quantity of looſe powder, I put a little piece of writing paper upon it, by which the ſhell went much farther than when loaded with the ſame quantity of powder, without paper.

Three cylindric ſhifting chambers of different lengths holding the ſame quantity of powder, produced the ſame range when full; but when they were not quite filled, the longeſt produced the greateſt range.

Two chambers in the form of a fruſtum of a cone, the largeſt baſe was at the bottom in one, and the ſmalleſt of the other; the firſt carried the ſhell farther than the ſecond.

The colonel tried two experiments more; the one between grained and mealed powder; and they were both found to be of an equal ſtrength: and the other he put a ſmall phial filled with water into the chamber amongſt the powder, and found its ſtrength conſiderably increaſed; that is, the ſhell went farther with the water than without it. The colonel tried likewiſe a cylindric chamber of about four inches long, with four vents, one at the bottom, one at the upper end, and two in the

the middle, all four at an equal diſtance from each other, ſo that when one was uſed, the others were ſtopped by ſcrews; and he found that the loweſt carried the ſhell fartheſt, and the ranges of the others diminiſhed in proportion as they were diſtant from the bottom.

Many uſeful obſervations may be made on theſe experiments. Firſt, that the vent placed near the bottom of the chamber is more advantageous than any where elſe; though this has been found ſo in mortars, we are not certain that it is the ſame in guns, which ſhould therefore be tried; and if it be found the ſame, the query is, whether the bottom of the bore ſhould not be flat, inſtead of roundiſh, as is the cuſtom, or to pierce the vent from the breech moulding, as colonel *Weideman* did, or elſe as the *French* do in ſome of their mortars, with a ſmall cup at the end of the chamber to receive the vent. From hence it appears how inaccurate experiments have hitherto been made, and how neceſſary it is to make new with all the neceſſary precautions, in order to improve artillery, and to bring it to perfection.

Before theſe experiments were made, it was imagined, that when the vent is in the middle of the chamber the range would be the greateſt, becauſe if a tube filled with powder was lighted in the middle, the powder would be burnt in half the time it would if lighted at one end, and it was ſuppoſed the greater quantity burnt before the ſhot was ſenſibly moved from its place, the greater force it would receive; but notwithſtanding this plauſible reaſon, experiments have evinced the contrary.

The next obſervation to be made is, that the concave chamber is preferable to the cylindric, and this to any other; which has not hitherto been conſidered: the *Spaniards* make theirs ſpheric, the *French* in the ſhape of a pear; and we conical. The various opinions authors and artilleriſts have concerning the figure of chambers are very extraordinary. The chevalier *Belidor* eſteems the conical the beſt; but his reaſoning concerning the pro-

perties

perties of different chambers in page xxiv. of his *Bombardier François*, are so very weak and inconsistent, that it is needless to answer them: how so great a man as he is in all other respects could descend to such vulgar errors is inconceivable.

Mr. *Robins*, in page 41, old edit. pretends, that the figure of a chamber has no effect upon the action of powder, without shewing the least reason for his assertion. Count *Bukeburg* will have a parabolic form, imagining, that if the fire was introduced to the focus, the rays of lighted powder would, by the nature of the figure, reflect into parallel direction in the same manner as the rays of light: supposing this was true, the shell would not receive a greater force by it, because a fluid acts always in a perpendicular direction to the surface it strikes; thus in a globe the directions of the fluid tend all to the center, as we shall prove in the fifth theorem; and when all the forces are reduced to the direction of the shell, it is that force reunited into one direction that produces the real effect, and not the partial ones. This not only refutes what his lordship said, but likewise *Belidor* and *Robins*, as having all split upon the same rock. It is not the inward figure of the chamber, but its entrance, which produces the effect; because the smaller it is, the nearer it reduces the effect into the direction of the shell. This is likewise proved by the practice of making sky-rockets, which being choaked at the end, by which it confines the force of explosion into a narrow stream, and increases its violence so as to make the rockets rise so high as they do; whereas if the opening was not confined, they would scarcely rise at all. The notion that a concave chamber with a narrow neck shakes the mortar violently without increasing the force of explosion, or the range, is so inconsistent with the laws of motion, that it merits not the least attention.

It is the general opinion of the artillery officers, that a mortar or gun carries farther when it is warm by much firing than when cold, or in the heat of the day than in the

the morning. The conſtant practice by ſea and land is, that when the guns are much heated to diminiſh their charges, from the notion that they carry them much farther; which is a miſtake. For when guns are much heated, they are liable to be ſpoiled; and it is prudent to leſſen their charges in that caſe. For it appears from my firſt four experiments made in the cool of the morning, that the ranges were greater than thoſe when the weather grew warm. The *chevalier Belidor* made ſeveral experiments for that purpoſe, which I have ſeen, and which are mentioned in general only in his *Bombardier*, page xxxviii; but the particulars are as follows: ſeveral mortars were fired in the cool of the morning; the ſame trials were repeated in the middle of the day when it was very hot, and the ranges in the morning were always greater than thoſe in the heat of the day: but as this was not ſufficiently ſatisfactory, the chamber of a mortar was heated with lighted charcoals, as hot as could be without endangering the powder from taking fire; the range in this ſtate of heat was much ſhorter than when the mortar was quite cold. It is true that heat will dry the powder, and gives it a greater force, if it remains a certain time in the chamber, which is not the caſe in briſk firing; and dried powder is better than when it is damp; yet the elaſticity of the air is much increaſed by cold, and relaxed by heat; I mean from the ſtate of the atmoſphere.

Having ſaid every thing neceſſary in reſpect to the length of guns, we are now to conſider their thickneſs or ſtrength of their ſeveral parts, which ſhould be proportional to the efforts of fired powder; but its abſolute force cannot be determined otherwiſe than by experiments. The weight of the guns depends on the charge of powder, and on their length; and though the charge has been leſſened from that given formerly, yet the thickneſs of metal remains in general the ſame; nor have the experiments with light guns mentioned before,

prevailed

prevailed as yet in diminiſhing the weights of larger calibers.

I had two braſs 12 pounders caſt for admiral *Keppel*, according to the conſtruction in page 54; they weighed 13 : 1 : 0, which ſtood the full ordnance proof; the old weigh 29 : 1 : 0.

I had alſo ſeveral eighteen braſs pounders caſt for the *India* Company; ſome of them were lately proved at *Woolwich* with fifteen pounds of powder, though the charge in ſervice ſhould not exceed ſix pounds: they weigh 2400, and are 9 feet long: a 24 pounder would in the ſame proportion weigh 3200, and their length 9 feet 8 inches. I look upon this proportion to be ſufficiently ſtrong for braſs battering pieces, though much lighter than the preſent; even a 32 pounder of that length would weigh only 4200, and in my opinion make better battering pieces; becauſe the largeſt ſhot makes a breach ſooner than a ſmaller, and the ancients made uſe of 48 pounders for that purpoſe; but on account of their unweildineſs they were reduced to 24 pounders, not that they were better, but more manageable. That theſe guns are ſufficiently ſtrong appears not only from their proof, nor that they weigh twice as much as thoſe of the light nature, but likewiſe from ſome old 32 iron pounders caſt in king *Charles* the ſecond's time; ſome of them remain ſerviceable to this day, and they weighed 4200 only.

The firſt caſt guns were made of what is called gun metal, and this metal continued for a great while before caſt iron was uſed; but in time, as artillery became more in uſe, the number of cannon became very great, and to leſſen the expence iron guns were invented; but the opinion of their being liable to burſt when much heated by firing, was the cauſe of making them heavier than the braſs; and as ſome did burſt in effect, either through wrong management, or the unſkilfulneſs of ſome founders, this notion has prevented the more general uſe that might be made of them to this day. But for what

reaſon

reaſon we make them much heavier now than in king *Charles*'s time cannot be accounted for; for the preſent 32 and 42 pounders weigh 54 and 55 or 56 hundreds; whereas they weighed formerly only 4200 and 5200. This cannot be owing to better ore, or to more ſkilful founders; becauſe I have ſeen iron caſt by the *Carron* company that could not be broke by any means, but would flatten and tear like braſs. I had two iron three pounders caſt by that company for lord *Egmont* that weighed 3 : 3 : 0 each, which ſtood the full ordnance proof with three pounds of powder; whereas their charge in ſervice ſhould never be more than one fourth, or at moſt one third of that quantity. I had ſince two ſix and two twelve pounders caſt by the ſame company for the *Portugueſe* ſervice; the firſt weighing 7 : 3 : 0, and the others 15 : 2 : 0; and though they are not yet proved, I will anſwer for their ſtrength. The old 6 pounders weigh 17 : 1 : 0, and the 12 pounders 32 : 2 : 0.

That iron pieces are preferable to braſs evidently appears from the experience we had in the laſt war; for at *Belleiſle* the braſs guns were ſoon rendered uſeleſs, and iron ſhip guns were uſed to finiſh the ſiege. I have been aſſured by ſeveral artillery officers, that in all the ſieges we made in the laſt war, they were obliged to uſe iron guns, becauſe the braſs did never ſtand great firing, though they weigh 400 more than the iron.

This is eaſily accounted for, becauſe gun metal is a compoſition of copper and tin: the copper requires a red heat to melt, and tin only a common fire; ſo that when the gun is heated by much firing, the tin melts, and the copper alone remains to ſupport the force of exploſion; by which the muzzle droops, and the vent widens ſometimes to that degree, as a man's fiſt may go in it. To make the vent more durable they put in a piece of copper to grain it, as it is called. This grain is fixed into the mould before the melted metal is let in to make them unite together; but as copper is ſofter than gun metal, inſtead of making the vent more durable,

durable. as it is imagined, it rather weakens it in my opinion. If a ſteel grain was put in, provided it can be united with the metal, there is no doubt but it would be better than any other metal; for it has been found by experience, that a new vent of iron being made, it was ſcarcely ever ſpoiled afterwards. The *French* had a gun with an iron vent at *Belleiſle*, which was found after the ſiege to be the only one that ſtood out the ſiege without being ſpoiled. To make a compoſition of gun metal of a durable ſubſtance, the ingredients ſhould be ſuch as require the ſame degree of heat to melt; but no ſuch metals have as yet been diſcovered. It is true, that ſome *Saxons* pretend to have that ſecret; but as they have not yet made any guns of it, no dependance can be made on it.

As good iron caſt from virgin ore has all the quality that can be deſired in gun metal, and not one burſt all this war that I heard of, what occaſion is there for any other? and there is ſuch a plenty of it every where, eſpecially in *England*, and the founders are ſo expert in their buſineſs at preſent, that they can make it more or leſs malleable, as they pleaſe; beſides, the expence is ſo much leſs, as 9 or 10 to one; which one would think ſhould be a ſufficient motive to uſe no other. Although the artillery officers agree, that iron battering pieces are preferable to braſs, yet to make field pieces of iron they by no means approve of, becauſe they ſay it would be too dangerous to ſtand by them in time of action; but what ſhould prevent a proper trial to be made? And if it does not ſucceed, the expence would be inconſiderable; and if it does, as I do not doubt it will, what a prodigious expence would be ſaved.

I would adviſe to have two ſix pounders caſt of the ſame weight as the braſs, and proved in the ſame manner; then fire them three hundred rounds as quick as they can, with a pound and a quarter of powder, in the ſame manner as the braſs were tried; and if they ſtand ſuch a trial, let the officers then judge whether there can

be any danger in uſing them. We are not to judge raſhly in a matter of ſo great importance as this, without a full and ſufficient proof. It is not the opinion of a few perſons we are to judge by, but by matter of fact. I may poſſibly be miſtaken, though I think to have ſufficient proofs of what I aſſert; and therefore recommend proper trials to be abſolutely certain.

As we propoſe chambers to be made in all calibers from an 18 pounder upwards, it will not be improper to ſhew here their advantage, firſt from experiments, and afterwards from theory. General *Williamſon* and the reſt of the artillery officers made likewiſe ſeveral experiments with ſhells from a bomb veſſel in the harbour of *Mahon* in 1746. Of which I ſhall only inſert the range of the fifth, which was 4570 yards; the mortar was loaded with 35 ℔ and 10 ounces, the ſhell weighed two hundred or 224 pounds, and the angle of elevation 45 degrees; and the range of the ſeventeenth experiment with a ten inch mortar was 3787 yards; the ſhell weighed 97 lb. and the mortar loaded with 12 pounds of powder. Now the charge of the firſt mortar being about 5.6 parts of the weight of the ſhell, produced a greater range than the 18 pounder gun loaded with half the weight of the ſhot; the ſecond mortar was loaded with no more than an eighth part of the ſhell's weight, and yet its range differed but 373 yards from that of the gun. This great difference between the forces of powder, when it was confined in a chamber, and in a gun without a chamber, can ariſe from no other cauſe, than that the direction of its force is nearer to that of the ſhell than it is to that of the ſhot. It is true, that the reſiſtance of the air is leſs on the ſhell than on the ſhot; but, on the other hand, the bore of the mortar is ſo ſhort, and ſo wide in compariſon to the width of the chamber, that the exploſion of the powder can only act upon the ſhell before it is ſenſibly moved from its place; inſtead of which it acts upon the ſhot till it leaves the gun. All this being conſidered, the advan-

tage of chambers in guns, as well as in mortars, will be found to be very confiderable.

We fhall prove this likewife by theory hereafter in theorem the vth.

Though we have fhewn that the theory of powder is as yet defective in many refpects for want of a fufficient number of good experiments, thofe which have hitherto been made were with too fmall quantities, as can by no means be depended upon: fince the fmalleft error in a few grains becomes very confiderable in the charges of artillery pieces; neither do we know the time of the degrees of inflammation. All that can be done, is to fuppofe that it fires all at the firft inftant, and proceed upon this fuppofition, though erroneous, till fuch time that the law of inflammation has been difcovered.

THEORY of POWDER.

THEOREM I.

The explofion of fired powder produces a permanent elaftic fluid, and forms a fphere, if not prevented by any external obftacle.

AUTHORS agree, and experience fhews, that fired powder produces an elaftic fluid; and if it be fired under an exhaufted receiver, the mercurial gage defcends; and though it rifes again when the heat is abated, yet it remains always below its common ftandard; which plainly fhews, that the fluid produced by fired powder is elaftic and permanent.

Again, if a fmall quantity of powder be fired on a table, its flame rifes in the form of a femi-fphere; and in whatever veffel powder is confined, the explofion will always burft it in the weakeft part, if the elaftic force be

be ſufficient. Conſequently fired powder acts on every ſide alike; which could not happen, unleſs the exploſion was ſpherical.

REMARK.

Though authors agree, that powder produces an elaſtic fluid when fired, yet they differ in the manner of it. Moſt of them are of opinion, that powder is only condenſed air, which being heated by the exploſion, as well as the natural air contained between the interſtices of the grains, produced this elaſtic fluid. Others affirm, that the air contained in powder exiſts in its natural ſtate; which being heated expands itſelf, and produces the exploſion. But this is contradicted by the above-cited experiment: for when the heat in the receiver is abated, the mercurial gage ſhould, according to this ſuppoſition, riſe again to the ſame height as it was before; which is contrary to experience.

Sir *Iſaac Newton* ſays, in his *Optics*, Query 10, that if ſalt of tartar be mixed with powder, and that mixture be heated till it takes fire, the exploſion will be more violent and quick than that of powder alone; which can proceed from no other cauſe, than the action of the vapour of the powder upon the ſalt of tartar, whereby that ſalt is rarefied; and therefore the exploſion of powder ariſes from the violent action, whereby all the mixture being quickly and vehemently heated, is rarefied and converted into fume and vapour; which vapour, by the violence of that action becoming ſo hot as to ſhine, appears in the form of flame. Thus far Sir *Iſaac Newton*.

But whether the elaſtic force of powder be owing to the expanſion of air, or to ſome other fluid produced by the ingredients of which it is made, is not material in reſpect to what follows; it being ſufficient for our purpoſe, that the force produced thereby acts chiefly according to the ſame law as all other elaſtic fluids; which it will be proved to do by experiments hereafter.

THEOREM II.

The densities of the same quantity of an elastic fluid, contained in different capacities, are as these capacities inversely.

For the same quantity of matter being reduced to half the bulk, will have its parts twice nearer each other; if it be reduced to one third or one fourth of the bulk, the parts will be three or four times closer to each other; and whatever the bulk is reduced to, the parts will always be closer to each other in the same proportion. And since the density of matter consists in the closeness of the parts, it is evident that the density increases as the bulks diminish; consequently, the densities of the same quantity of an elastic fluid, contained in different capacities, are as these capacities inversely.

COR. I.

Hence it follows, that the densities of different quantities of the same elastic fluid, contained in the same or equal capacities, are as these quantities. For if twice the quantity be contained in the same capacity, the density will be double; if three or four times the quantity be contained in the same capacity, the density will be triple or quadruple; and therefore, in general, whatever the ratio is between the quantities contained in the same or equal capacities, that of the densities will always be the same.

COR. II.

Hence the densities of different quantities of the same elastic fluid, contained in different capacities, are as the quantities directly, and the capacities inversely. For because the densities of the same quantity of an elastic fluid,

fluid, contained in different capacities, are as these capacities inversely, by Theorem II. and the densities of different quantities of the same fluid, contained in the same or equal capacities, are as these quantities directly by Cor. I. it is evident, that if the quantities are different, as well as the capacities, the densities will be as the quantities directly, and the capacities inversely.

THEOREM III.

The intensity of heat produced by the explosion of fired powder, will be as the density of the fluid.

For the heats of the same quantity of powder, fired in different capacities, will be as these capacities inversely; and the heats of different quantities, fired in the same or equal capacities, are as these quantities directly. Therefore the intensity of heat produced by different quantities of fired powder in different capacities, is as the quantities directly, and the capacities inversely; or as the densities by the last Corollary.

THEOREM IV.

The elastic force produced by an explosion of fired powder, is in the compound ratio of the density of the fluid, and the intensity of heat.

For the elastic force of condensed air is as the force of compression, and the force of compression is as the density; and since the elastic force is also increased by heat, it is manifest, that the elastic force is in the compound ratio of the density of the fluid, and the intensity of heat.

This may likewise be proved as follows: since every particle of the fluid has the same degree of heat, and the total force of the explosion is equal to the sum of the forces of all the parts; the elastic force of the ex-

plosion is therefore in the compound ratio of the heat of one particle, and the sum of all the particles, or, which is the same, the density of the fluid. Consequently the elastic force, produced by the explosion of fired powder, is in the compound ratio of the density of the fluid, and the intensity of heat.

REMARK.

Mr. *Robins* supposes the elastic force, produced by the explosion of fired powder, to be as the density of the fluid, which is the case of condensed air void of heat; and therefore he supposes the increase of force, produced by heat, to be constant, in his proposition; but finding afterwards that the force increased by heat, he says, we have hitherto supposed powder, when fired, to be equally hot with iron, at the beginning of its white heat; but we have observed, that it varies according to the quantity of powder fired together. The flame therefore may have all the different degrees, from that of a languid red reat, to the heat sufficient for the vitrification of metals; which agrees exactly with what has been said in the last Theorem. That heat increases greatly the elasticity of air, is known by heating an empty bottle, well corked, in boiling water; for it will either drive the cork out, or else burst the bottle. It is likewise well known, that the steam of boiling water produces a great elastic force, and perhaps more than fired powder; although cold water seems to be entirely void of elasticity, since it cannot be compressed by any force we know of. Hence it seems as if cold water was in its densest state; and it appears very probable, that the density of air has its limit, beyond which it never can be reduced.

COR. I.

Since the intensity of heat is as the density of the fluid, by Theor. III. and the elastic force of fired powder

der is in the compound ratio of the denſity of the fluid, and the intenſity of heat, the elaſtic force of fired powder is therefore in a duplicate ratio of the denſity; and, conſequently, by Cor. II. of Theor. II. the elaſtic force of fired powder is in the duplicate ratio of the quantity of powder directly, and the duplicate ratio of the capacities inverſely.

Cor. II.

Hence, if the quantities of powder are in the ſame ratio as the capacities in which they are contained, the forces of exploſion will be equal.

For ſince theſe forces are in the duplicate ratios of the quantities of powder directly, and the duplicate ratio of the capacities inverſely; the ſingle ratios being equal by ſuppoſition, the duplicate will likewiſe be equal.

Cor. III.

By a known property of fluids in general, the preſſure againſt any ſurface is in the compound ratio of the impreſſing force, and the ſurface preſſed; and ſince, of all equal ſolids, the ſphere has the leaſt ſurface, it is evident, that of all capacities which contain the ſame quantity of powder, the ſpheric is the ſtrongeſt, or, which is the ſame, is the leaſt preſſed.

Cor. IV.

Hence, the forces againſt ſpheric ſhells, filled with quantities of powder proportional to their capacities, are to each other as the ſquares of their radii, for the forces of exploſion being equal by Cor. II. the forces againſt theſe ſhells will be as the ſurfaces preſſed; and they being as the ſquares of the radii, the forces impreſſed will be in the ſame ratio of the ſquares of the radii. Conſequently, if the thickneſs of ſhells are pro-

portional to their radii, they will be equally ſtrong, ſince their thickneſs will be to each other as the ſquares of the radii, and conſequently as the impreſſing forces.

Cor. V.

It is alſo manifeſt, that the forces againſt the concave part of the cylindric ſurfaces, filled with proportionable quantities of powder, are as theſe ſurfaces: for the forces of exploſion are equal in this caſe, by Cor. II. and therefore the impreſſing forces are as the ſurfaces preſſed. Now becauſe cylindric ſurfaces are in the compound ratio of their radii and their axes; if the axes are equal, the forces are as their radii; if the radii are equal, as their axes; and if they are ſimilar, as the ſquares of the radii or axes.

Remark.

When pieces of artillery are loaded with charges proportional to the weights of their ſhots, the axes of the charges are proportional to their radii; and as they are equally preſſed by the elaſtic force of powder, as far as the charge reaches, their outward ſurface ſhould be ſo far parallel to their inner one, and the thickneſs of the metal made proportional to the radii of their baſes; or becauſe the diameters of the bores are proportional to the diameters of the ſhots, and from thence to the mouth, the outward figure ſhould be that deſcribed by the rotation of a cubic hyperbola about one of its aſſymtotes, which is placed in the axis of the bore: this appears from what has been ſaid in Cor. I. after Theor. IV. But becauſe of the action of the ſhot againſt the inſide of the piece, the thickneſs of metal muſt be ſomewhat more towards the muzzle than what this figure makes it.

Before the foregoing Theory can be applied to any particular example, it is neceſſary to find the ratio between

tween the preſſure of the atmoſphere and the elaſtic force of powder, which is very difficult, becauſe authors diſagree very much in their experiments on that head.

For Mr. *Robins* ſays, that the air contained in powder is but 244 times denſer than that we breathe; and that its elaſticity cannot be increaſed above five times by the heat of the exploſion; and from thence he concludes, that the elaſtic force of fired powder is about 1000 times greater than the preſſure of the atmoſphere. The late Mr. *Hawkſbee* aſſured me, that he found, by ſeveral experiments, the flame of powder to occupy about 5000 times the ſpace of the powder unfired. Mr. *Belidor* ſays, that, by ſome experiments he made, he found that ſpace to be about 4000 times increaſed, and that the ſame thing had been found by Mr. *Amonton*. Mr. *Bigot de Morogues* ſays, in page 65, that he found that ſpace to be from 4 to 4500 times; and laſtly, *Daniel Bernoullie* found it to be from 4 to 6000 *.

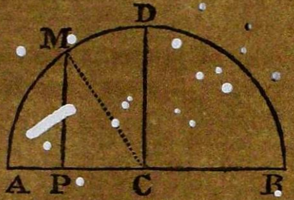
It is certain that theſe experiments are attended with great difficulties, on account of the quickneſs with which the powder fires, and the flame diſappears. Another difficulty ariſes from the inequality of the preſſure of the atmoſphere, as well as from the different ſtrength of powder; and therefore it is impoſſible to arrive at any tolerable degree of exactneſs, notwithſtanding all the precautions that can poſſibly be taken in making the experiments: ſo all that can be expected will be to take ſuch a number as agrees neareſt with the experiments made on the velocities of ſhots, which is that of Mr. *Belidor*'s, as being a mean between the greateſt and leaſt of theſe ſeveral experiments.

* Mr. *Boyle* ſays, that the greateſt denſity of air is to the greateſt rarefaction, as unity to 520,000.

THEOREM

THEOREM V.

The force of an elastic fluid against any part of a spheric surface described by the arc DM *about the radius* CD *as an axis, perpendicular to the diameter* AB, *is to the absolute force, as the solid described by the segment* PMDC *terminated by the sine* PM *of that arc, is to the cylinder of the same base and altitude; and the force against the semi-sphere is to the total force, as the semi-sphere to the circumscribed cylinder.*



Draw the radius CM; then, by the nature of fluids, the surface is pressed in a direction perpendicular to every point; whence the absolute force in the direction CM is to the force impressed at the point M, in the direction PM as CM is to CP; and as this happens in respect to every point in the arc MD, the force impressed on the arc MD, will be to the absolute force as the area PMDC is to the rectangle made by CP and CD: consequently the force against the surface described by the arc MD about the axis CD, is to the absolute force as the solid described by the segment PMDC in that rotation to the cylinder, described by the rectangle PC and CD; and the force against the semi-sphere is to the absolute force, as the semi-sphere is to its circumscribed cylinder.

Mr. *Robins* and Mr. *Morogues* have supposed, that the force against the semi sphere was equal to that against the circle AB of the base: but they did not consider, that the directions of the forces against the different parts of the sphere were oblique to the direction CD, in which the sphere is supposed to move; and therefore the total force must be less than the absolute force.

This

This Theorem agrees exactly with Sir *Isaac Newton*'s prop. 35, book ii.

Cor. I.

Since the sphere is the two-thirds of its circumscribed cylinder, it follows that the ball is acted upon by the two thirds of the absolute force of the powder.

Example I.

If we suppose C P to be a third part of the radius C A, it will be found by geometry that the cylinder, whose radius of the base is C P, and altitude C D, is to the solid described by the space C P M D about the axis CD; or the total force of the powder is to that part which acts upon the surface described by the arc M D, as 900 to 875: and since the semi-sphere is acted upon by the two thirds of the total force of the powder, and if the quantity be the same in both causes, the force of explosion upon the sphere will be to the part which acts upon the surface described by M D, as 600 to 875; which shews that the force against the surface is only 25 parts less than the absolute force 900: whereas the force against the semi-sphere is but 600, the two thirds of the absolute force 900.

Example II.

If C P be one half of the radius C A, then it will be found in the same manner as before, that the circumscribed cylinder is to the solid described by the space C P M D; or the total force of the powder is to the part acting upon the surface described by the arc M D, as 900 to 841; and the force acting upon the sphere acting upon this solid, as 600 to 841.

Cor. II.

Hence it is manifeſt that chambers, whoſe diameters are but one third of the diameter of the bore, are more advantageous than thoſe whoſe diameters are one half, as they are made at preſent in our mortars; and if they were ſtill leſs they would be better; which however may have its limits. This agrees exactly with ſeveral experiments made for that purpoſe: for Mr. *Hawkſbee* tried ſeveral times a little mortar, which had three ſhifting chambers of the ſame capacity, and always found that the chambers which were narroweſt carried the ſhell fartheſt.

As the firſt part of artillery was printed before the 18 braſs pounders have been proved, and the general conſtruction of theſe pieces appears to be properly adapted to braſs guns for the land ſervice, I ſhall inſert it here, in order to ſhew how much the metal might be diminiſhed.

General conſtruction of braſs cannon for the land ſervice.

Let the length A B, ſee Plate I, be 21 diameters of its ſhot, the thickneſs of the metal at the breech and vent 18.5 parts, and at the mouth 9; the reſt of the conſtruction may be the ſame as that given in page 46.

Weight

Weight and dimensions of brass guns for land service.

Calib.	Length.	Weight.
6	6 : 1	8 : 0 : 4
9	7 : 0	12 : 0 : 6
12	7 : 8	16 : 0 : 8
18	9 : 0	24 : 0 : 12
24	9 : 8	32 : 0 : 16
32	9 : 8	42 : 0 : 20
42	9 : 8	52 : 0 : 24

It must be observed, that we made the lengths of the 24, 32, and 42 pounders the same, being sufficient for battering pieces, and reduces the weight of the two last considerably: that these pieces are sufficiently strong appears from the old iron 32 and 42 pounders cast in king *Charles* the second's time, which weighed no more. But it must be remembered, that the charges of these pieces should never exceed one third of their shot's weight, because that charge has been found sufficient by experiments in all battering pieces.

Iron Field Pieces.

Calib.	Length.	Weight.
3	3 : 3	2 : 1 : 0
6	4 : 1	4 : 2 : 0
9	4 : 8	6 : 3 : 0
12	5 : 1	9 : 0 : 0
18	5 : 10	13 : 2 : 0
24	6 : 5	18 : 2 : 0

We have inserted this table of the dimensions of iron field pieces, in order to shew how they may be constructed, in case it should be thought proper to make trial of their strength. Their length is 14 diameters of the shot, the thickness of metal at the breech and vent 18 parts, and 9 at the mouth; the rest of the construction is the same as that of the light brass field pieces.

The proof of these pieces should be made with one half of the shot's weight of powder,

powder, and their charge in ſervice one fourth, which is the ſame as thoſe of braſs.

If theſe pieces are caſt from good virgin ore by a ſkilful founder, ſuch as the *Carron* company, and ſome others, without mixing any pig iron, there cannot be the leaſt doubt but they will be as uſeful, and laſt longer than the light braſs; becauſe their vents ſcarcely ever ſpoil, and the pieces never bend at the neck.

The reader may perhaps be glad to know the greateſt velocities that ſhot can have, and their greateſt ranges, which often have been ſought for by moſt artilleriſts, but they could never agree; for which reaſon we ſhall inſert them in the following table.

The firſt column contains the weight of the ſhot, the ſecond the number of feet moved over uniformly, in a ſecond by the greateſt velocity; and the third the greateſt random ranges which theſe ſhots can poſſibly have, let the charges be ever ſo great.

Shot.	Velocities.	Ranges.
3	615. 7	2326
6	691. 3	2932
9	739 0	3352
12	775. 3	3688
18	826. 5	4191
24	866. 8	4610
32	912. 9	5113
42	955. 5	5602
48	976. 4	5849

This ſhews that ſmall calibers can never go ſo far as greater, and contradicts the common practice of making ſmall calibers longer in proportion, in order to go farther.

A ten inch ſhell may go to 5384 yards at an elevation of 45 degrees, and a thirteen to 7041 yards at the ſame degree of elevation; which is upwards of four miles. Again, the greateſt velocity a leaden bullet of three quarters of an inch diameter can poſſibly have, is at the rate of 395 feet a ſecond, when uniformly continued.

The

The demonſtration of theſe velocities and ranges is given in the appendix: Mr. *Robins* thinks to prove, in his ſeventh problem, that the velocity of the foregoing leaden bullet is 1668 feet in a ſecond, which is more than four times greater than that above; and what is more extraordinary, he pretends to have found the ſame velocity by experiments. As he ſeems to build his theory upon Sir *Iſaac Newton*'s principles, had he read the 40th propoſition, book ii. he muſt have been convinced of his miſtake; and from over-rating the velocities, the reſiſtance of bodies moving in the air is, according to his computation, above twenty-four times too great in a 24 pounder.

Height.	Diſtance.		Height.	Diſtance.	
Yds.	Yards	Miles.	Yds.	Yards	Miles.
1	3735	2. 12	26	19048	10. 82
2	5278	3. 00	27	19410	11. 03
3	6470	3. 67	28	19767	11. 23
4	7470	4. 24	29	20107	11. 42
5	8353	4. 74	30	20460	11. 62
6	9150	5. 20	31	20800	11. 82
7	9863	5. 60	32	21133	12. 00
8	10566	6. 00	33	21459	12. 20
9	11206	6. 36	34	21780	12. 38
10	11800	6. 70	35	22100	12. 55
11	12390	7. 04	36	22413	12. 73
12	12940	7. 35	37	22720	12. 91
13	13468	7. 65	38	22895	12. 97
14	13977	7. 94	39	23320	13. 20
15	14468	8. 22	40	23631	13. 40
16	14942	8. 49	41	23919	13. 59
17	15402	8. 75	42	24209	13. 75
18	15850	9. 00	43	24500	13. 92
19	16283	9. 25	44	24780	14. 08
20	16706	9. 49	45	25059	14. 24
21	17118	9. 72	46	25336	14. 40
22	17521	9. 95	47	25610	14. 55
23	17915	10. 18	48	25880	14. 70
24	18300	10. 40	49	26148	14. 85
25	18678	10. 61	50	26414	15. 00

As

As the diſtance a ſhip may be ſeen at ſea is eſteemed uſeful, we have given them from one yard high to 50, from the ſurface of the ſea, and the reſpective diſtances in yards and miles: they are deduced from the roundneſs of the ſea's ſurface, according to the prob. in art. 411, of our treatiſe of mathematics: the mean diameter of the earth being 6548856 *French* toiſes, according to our determination; which being reduced into *Engliſh* yards, gives 7,1447018 for its logarithm; to which adding continually the logarithm of the height, gives the logarithm of the ſquare of the diſtances in yards; and the diſtances in yards being divided by 1760, the number of yards in a mile, gives the number of miles which theſe diſtances contain.

The navigator may always know the height he is from the ſurface of the ſea, when he obſerves the hull of another ſhip, at the water edge, then he has the diſtance marked in the table againſt the height from which he obſerves; but if any part of the ſhip he obſerves is hid by the ſurface of the water, he muſt give a gueſs how high the part hid is; then if he adds the diſtance againſt that height expreſſed in yards, to that againſt the height he ſees, the ſame will be the true diſtance to the ſhip.

Example. Suppoſe he obſerves a ſhip from a height of 15 yards, and the part of the ſhip hid is 5 yards; then the diſtance 6470 againſt 5 yards, added to the diſtance 14468 againſt 15 yards, gives 20938 yards or 12 miles nearly for the diſtance required.

We have not conſidered the refraction of the air, by which the ſhip may be ſeen a little farther than what is marked in the table. But if the ſhip is within the horizon, and the height of the part ſeen between the ſurface of the water and the horizontal line, then the diſtance anſwering to this height, ſubtracted from the firſt, gives that between the two ſhips.

ARTILLERY.

ARTILLERY.

PART I.

WEIGHTS AND MEASURES.

TO proceed with order in the ensuing work, it is proper to mention the necessary weights and measures used in Artillery, for the better understanding the use and construction of the tables.

An inch is the least common measure; 12 inches make a foot, 3 feet a yard, a pole is 16.5 feet, a furlong 40 yards, and a mile 1760 yards. These measures are also sub-divided into 10, 100, and 1000 parts.

Avoirdupois weight is used in Artillery, and in all heavy commodities; a drachm is the least weight, 16 of which make an ounce, 16 ounces a pound, 14 pounds a stone, 112 pounds a hundred weight, 20 hundreds a ton.

As *French* weights and measures are proper to be understood in Artillery, we shall give the proportion between ours and theirs. The gentlemen of the Royal Society in *London*, in conjunction with those of the Royal Academy of Sciences at *Paris*, are said to have, with great

great accuracy, compared our weights and meaſures with thoſe of *France*; the reſult of which is,

The *Engliſh* foot to the *French* royal, as 107 to 114. The *Engliſh* pound avoirdupois to the *French* pound marc, as 63 to 68. Whence 100 *French* pounds make very near 108; and therefore their hundred weight is to ours, as 108 to 112; that is, as 27 to 28, according to this proportion.

The proportion of the *French* and *Engliſh* foot is nearly exact; for I tried two *French* ſectors, the one made by *le Maire* ſeemed to be exactly divided, and I found that three *French* inches make 3.2 of ours; ſo that the *French* foot is to ours as 32 to 30, which is near 114 to 107; ſince if 114 be multiplied by 15, the product will be 1710; and 107 multiplied by 16, gives 1712; which exceeds the former by 2 only.

But the proportion of the *French* and our weights is by no means right, as will appear hereafter, when we give tables of ſhots. It is hard to judge how ſuch a miſtake could happen, unleſs the weights they compared were not thoſe uſed in the Artillery there and here.

Before we proceed any farther, it will be neceſſary to premiſe ſome geometrical propoſitions, which ought to be known, in order to underſtand ſeveral parts of this work.

I. The diameter of the circle is to its circumference, as 113 is to 355 nearly.

II. The ſquare of the diameter is to the area of the circle, as 452 to 355.

III. The cube of the diameter is to the ſolid content of a ſphere, as 678 to 355.

IV. The cubes of the axes are to the ſolid contents of equialtitude cylinders, as 452 to 355.

V. The ſolid content of a ſphere is to the circumſcribed cylinder, as 2 to 3. Theſe propoſitions are demonſtrated in the Ninth Section of my Elements of Mathematics.

The

The following table contains the weight of a cubic foot, expreſſed in ounces, of the ſeveral ſubſtances ſpecified, which I have for the moſt part taken from Mr. *Cotes's* hydroſtatic lectures. Thoſe of gun metal have been computed from their mixture, and the caſt iron from the 9 pound ball, whoſe diameter is four inches, exceedingly near, according to Sir *Jonas Moor*.

Specific gravities of bodies.

Copper	—	9000	Steel	— —	7645
Tin	— —	7320	Marble	— —	2700
Gun metal	—	8784	Dry Oak	—	925
Caſt braſs	—	8000	Dry aſh	——	800
Lead	— —	11325	Dry maple	—	755
Iron	— —	7645	Dry elm	——	600
Caſt iron	—	7425	Dry fir	— —	550
Shells	— —	4892	Powder	——	880

For his father weighing ſeveral iron balls with a curious ſcale, found one nearly round, whoſe diameter was 6.63 inches, and weighed 41 pounds; from thence the diameter of a 9 pound ball is found to be 3.9995 inches, which being ſo very near 4 inches, by taking it as ſuch, no ſenſible error can happen in computation.

Having the weight of a cubic foot of theſe bodies, that of any parts may be found by proportion; and on the contrary, the weight of any part of a body being given, its ſpecific gravity, or the weight of a cubic foot, may be found. Thus a cubic foot, or 1728 cubic inches of gun metal, weigh 8784 ounces, or 549 pounds: then dividing 1728 by 9, we get 192 cubic inches; and dividing 549 by 9, we get 61 pounds. Hence 192 cubic inches of gun metal weigh 61 pounds.

Again: 1728 cubic inches of caſt iron, weighing 7425 ounces, or 464 pounds and an ounce, which we ſhall neglect; then 1728 divided by 16, gives 108, and 464 divided by 116, gives 29. Hence 108 cubic inches of caſt

caſt iron weigh 29 pounds. Theſe two examples will be uſeful hereafter in finding the weight of guns.

A ſhell, whoſe diameter is $12\frac{3}{4}$, weighs 192 pounds when loaded, as will be ſhewn; and 355 is to 678, as the content or weight 192, is to the content or weight of the cube 366.69 made by its diameter: but the cube 2072.67 of $12\frac{3}{4}$, is to the cube 1728 of 12, as the weight 366.69 is to the weight 1892 of a cubic foot, or the ſpecific gravity of ſhells.

Again: a cylinder of powder, whoſe axis and diameter are each 3.42 inches, contains one pound, or 16 ounces, as will be ſhewn hereafter; and 355 is to 452, as the weight 16 ounces of the cylinder is to the weight 20.372 ounces of the cube made by its axis: but the cube 40 of 3.42 is to the cube 1728 of 12, as the weight 20.372 is to the weight 880 ounces of a cubic foot, or the ſpecific gravity of ordnance powder.

Example I.

To find the diameter of an iron ball, whoſe weight is given, ſuppoſing that of a 9 pound is 4 inches. Say, the cube root, 2.08, of 9 pounds is to 4 inches, as the cube root of the given weight is to the diameter ſought; or if 4 be divided by 2.08, the cube root of 9, the quotient 1.923 will be the diameter of a one pound ball; which being continually multiplied by the cube root of the given weight, gives the diameter required.

This may be done in a ſhorter manner by making uſe of logarithms; for if the logarithm .2839793 of 1.923 be conſtantly added to the third part of the logarithm of the weight, the ſum will be the logarithm of the diameter. Suppoſe a ball to weigh 24 pounds, add the given logarithm .2839793, to the third part .4600704 of the logarithm 1.3802112 of 24, the ſum .7440494 will be the logarithm of the diameter of a ball weighing 24 pounds, which therefore is 5.5468 inches.

If

If the weight be expressed by a fraction, the rule is still the same; for instance, the diameter of a pound and a half ball, or of $\frac{3}{2}$, is found, by adding the logarithm .2839793, found above, to .0586971, one third of the logarithm of $\frac{3}{2}$; the sum .3426764, will be the logarithm of the diameter required, which therefore is 2.2013 inches.

The diameter of an ounce ball is found, by subtracting .4013733, one third of the logarithm of 16, from the logarithm .2839793, of one pound; as this logarithm is less than the other, an unit must be added to it; then the difference .882606, will be the logarithm of the ball's diameter, which weighs an ounce. This logarithm being continually added to the third part of the logarithm of the weight expressed in ounces, and an unit being taken from the sum, the remainder will be the logarithm of the diameter: thus, let the ball weigh eight ounces, add .3010300, the third part of the logarithm of 8, to the logarithm .882606 of one ounce; the sum .18363, after having subtracted unity, will be that of the diameter, which is 1.526 inches.

As the diameter of the bore, or the caliber of the piece, is made one twentieth part larger than that of the shot, according to the present practice, we have computed the following.

Diameters of the shots and calibers of English *guns.*

lb.	0	1	2	3	4	5	6	7	8	9	
0	0	1.923	2.423	2.775	3.053	3.288	3.498	3.679	3.846	4.000	Diam.
	0	2.019	2.544	2.913	3.204	3.668	3.668	3.86[illegible]	4.038	4.200	Calib.
1	4.143	4.277	4.403	4.522	4.635	4.743	4.846	4.945	5.040	5.131	Diam.
	4.349	4.490	4.623	4.748	4.866	4.981	5.088	5.192	5.292	5.386	Calib.
2	5.220	5.305	5.388	5.4[illegible]9	5.547	5.623	5.697	5.769	5.839	5.908	Diam.
	5.480	5.570	5.661	5.742	5.824	5.893	5.982	6.057	6.129	6.203	Calib.
3	5.975	6.041	6.105	6.168	6.230	6.290	6.350	6.408	6.465	6.521	Diam.
	6.273	6.343	6.410	6.475	6.541	6.604	6.666	6.707	6.788	6.846	Calib.
4	6.576	6.631	6.684	6.737	6.789	6.640	6.890	6.940	6.989	7.037	Diam.
	6.904	6.962	7.018	7.076	7.128	7.182	7.234	7.287	7.338	7.383	Calib.

The

The numbers in the first horizontal line are units, and those in the first vertical column the tens: the other numbers under the one, and opposite to the others, are the respective diameters of shot and calibers. Thus to find the diameter of the shot, and the caliber of a 24 pounder, look for the number 2 at the side, and for 4 at top; then the number 5.547 under 4, and opposite to 2, will be the diameter of the shot in inches and decimals, and the number 5.824, under the first, the caliber of the 24 pounder. Again, to find the diameter of the shot, and the caliber of a 36 pounder; look for 3 at the side, and 6 at the top, then the number 6.350, under 6, and opposite to 3, will be the diameter of the shot, and the number 6.666 under it, the caliber of the 36 pounder. In the same manner may be found the diameter of the shot and the caliber of any gun, under a 60 pounder: those above 48 are not used.

Diameters of the shots and bores of French guns by inches and decimals of their measure.

	0	1	2	3	4	5	6	7	8	9	
0	0	1.889	2.381	2.726	3.000	3.253	3.434	3.615	3.780	3.931	Diameter.
	0	1.950	2.469	2.827	3.111	3.351	3.561	3.749	3.920	4.076	Caliber.
1	4.072	4.203	4.327	4.444	4.55[illegible]	4.661	4.762	4.859	4.953	5.043	Diameter.
	4.222	4.390	4.487	4.608	4.723	4.833	4.958	5.039	5.134	5.229	Caliber.
2	5.130	5.214	5.295	5.375	5.451	5.526	5.599	5.670	5.739	5.847	Diameter.
	5.320	5.407	5.491	5.[illegible]84	5.653	5.730	5.806	5.880	5.95[illegible]	6.061	Caliber.
3	5.872	5.937	6.000	6.062	6.122	6.182	6.237	6.297	6.354	6.409	Diameter.
	6.089	6.157	6.222	6.288	6.349	6.411	6.468	6.530	6.589	6.646	Caliber.
4	6.463	6.517	6.569	6.621	6.672	6.722	6.77[illegible]	6.820	6.868	6.916	Diameter.
	6.702	6.758	6.812	6.806	6.918	6.971	7.022	7.072	7.122	7.172	Caliber.

This

This table is conſtructed upon the ſuppoſition that the diameter of a four pound ball is three *French* inches, according to their authors; and from thence, the difference between the logarithm of three inches, and one third of the logarithm of four pounds, gives the logarithm .2764347 of the diameter of a one pound ball, which being continually added to one third of the number of pounds of the ball, the ſum will be the logarithm of the diameter of that ball in inches and decimals. The windage of the *French* guns is but one twenty-ſeventh part of the ball's diameter; which, therefore, being added to the diameter, gives that of the caliber. Mr. *Saint Remy* gives a table of theſe diameters in page 136. Vol. i. new edit. in inches and duodecimals, without mentioning how it was conſtructed. In page 82, he ſays, that *Butterfield* has computed it, and that it is very exact. *Butterfield* was an *Engliſh* mathematical-inſtrument-maker eſtabliſhed at *Paris*.

This table agrees nearly with that given by *Saint Remy*, p. 136, as appears from the following numbers, where lines and points are reduced into decimals of an inch.

The firſt column contains the weights of the ſhot, the ſecond their diameters in inches and decimals according to *Saint Remy*, and in the third the ſame diameters according to our tables. Hence, our diameters are greater as far as a thirty-ſix pound ſhot, and leſs above it. Therefore the *French* table has not been conſtructed from the rule that the weights of ſhots are as the cubes of their diameters, unleſs ſome errors have been committed in their computations.

lb.	—	
24	5.444	5.451
36	6.229	6.237
39	6.417	6.409
41	6.518	6.517
46	6.776	6.771

The following table has been computed upon the ſuppoſition, that the *French* foot is to the *Engliſh* as 114 is to 107, as we have ſhewn in page 2; and from thence, the logarithm of the diameter of a *French* pound is .3039558, expreſſed in *Engliſh* inches and decimals.

As

As to the reſt of the diameters they are found in the ſame manner as before.

Diameters of the ſhots and bores of French *guns in* Engliſh *inches.*

	0	1	2	3	4	5	6	7	8	9	
0	0	2.013	2.537	2.904	3.196	3.443	3.659	3.852	4.027	4.188	Diameter
	0	2.088	2.631	3.011	3.315	3.570	3.794	3.994	4.180	4.343	Caliber.
1	4.338	4.478	4.610	4.734	4.853	4.966	5.074	5.177	5.277	5.373	Diameter
	4.499	4.554	4.781	4.910	5.032	5.150	5.262	5.365	5.472	5.571	Caliber.
2	5.466	5.555	5.642	5.726	5.808	5.887	5.965	6.041	6.114	6.186	Diameter.
	5.668	5.761	5.851	5.938	6.023	6.105	6.186	6.264	6.341	6.415	Caliber.
3	6.256	6.325	6.393	6.458	6.523	6.586	6.648	6.709	6.769	6.828	Diameter.
	6.488	6.559	6.629	6.698	6.765	6.830	6.895	6.958	7.020	7.086	Caliber.
4	6.886	6.943	6.999	7.054	7.108	7.162	7.245	7.266	7.318	7.368	Diameter.
	7.141	7.200	7.258	7.315	7.372	7.427	7.513	7.536	7.589	7.641	Caliber.

This

This table ſerves to compare the *French* calibers to ours; for example, the diameter 5.808 of a 24 pound ball is ſomething more than 5.769, that of our 27. That 6.393, of their 32, nearly equal to 6.408, that of our 37. That 6.648 of their 36, nearly equal to 6.684 of our 42.

The diameter of a *French* 9 pound ſhot is 4.188 inches of our meaſure, and its cube 73.453; and as the diameter of our 9 pounder is 4 inches, and its cube 64; therefore the *French* weight is to ours as 73.453 is to 64, or as 70 to 61 nearly: which differs greatly from the ratio mentioned before. Therefore 100 *French* pounds make 114$\frac{3}{4}$ pounds, and not 108, as the former proportion gives.

The proof that this ratio is the neareſt that can be given by two figures, we ſhall ſuppoſe, with Sir *Jonas Moor*, that the diameter of a 9 pound iron ſhot is 3.9995 inches; then as 114 is to 107, as 3.9995 is to 3.7593 *French* inches, whoſe cube is 52.899, and 70 is to 61 as 9 to 7.8428 pounds *French* weight. Therefore the cube 52.899 is to the cube 27 of 3, as the weight 7.8428 is to the weight 4.0004 pounds of the ſhot, whoſe diameter is 3 *French* inches, which agrees nearly with the ſuppoſition of the *French*: but if the ratio 68 to 63 be ſuppoſed, a 9 pounder *Engliſh* weighs 8,3382; then by proportion the weight of a ſhot, whoſe diameter is 3 *French* inches, will be 4.2558 pounds, or above a quarter more than 4 pounds; which is certainly more than it is poſſible not to perceive.

Iron

Iron grape shot from 1 *to* 39 *ounces.*

℥	0	1	2	3	4	5	6	7	8	9
0	0	.763	.9615	1.103	1.209	1.305	1.387	1.450	1.526	1.587
1	1.644	1.697	1.747	1.794	1.839	1.882	1.923	1.962	2.000	2.036
2	2.072	2.106	2.138	2.170	2.201	2.231	2.261	2.286	2.318	2.345
3	2.371	2.397	2.423	2.448	2.472	2.496	2.501	2.543	2.566	2.588

Whence

Whence the diameter of any bullet is found, by dividing 1.6706 inches by the cube root of the number, which ſhews how many of them make a pound; or this may be done in a ſhorter manner. From the logarithm .2228756 of 1.6706 ſubtract continually the third part of the logarithm of the number of bullets in the pound, and the difference will be the logarithm of the diameter required.

Thus the diameter of a bullet, whereof 12 weigh a pound, will be found by ſubtracting .3597270, a third part of the logarithm of 12, from the given logarithm .2228756, or, when this logarithm is leſs than the former, an unit muſt be added, ſo as to have 1.2228756, and the difference .8631486 will be the logarithm of the diameter ſought; which is .7297 inches; obſerving that the number found will always be a decimal, when the logarithm which is to be ſubtracted is greater than that of one pound; becauſe the diviſor is greater than the dividend in this caſe.

From the ſpecific gravity of lead, the diameter of any bullet may be found from its given weight. For ſince a cubic foot weighs 11325 ounces by our table, and 678 is to 355 as the cube 1728 of a foot, or 12 inches, is the content of the ſphere, which therefore is 5929.7 ounces; and ſince ſpheres are as the cubes of their diameters, the weight 5929.7 is to 16 ounces, or one pound, as the cube 1728 is to the cube of the diameter of a ſphere which weighs a pound; which cube therefore is 4.66263, and its root 1.6706 inches, the diameter ſought.

Sir *Jonas Moor* makes this diameter 1.69 inches: though he was very curious in his experiments, yet as the ſpecific gravities have likewiſe been determined by *Cotes* and ſeveral eminent men, it would be a preſumption in me to determine which of the two diameters is the moſt accurate; for which reaſon we ſhall give two tables, one of which of theſe ſuppoſitions, leaving the choice to the impartial reader.

Diameters

Diameters of leaden bullets from 1 to 39 in the pound, according to the author.

	0	1	2	3	4	5	6	7	8	9
0	0	1.671	1.326	1.158	1.05	.977	.919	.873	.835	.803
1	.715	.751	.730	.711	.693	.677	.663	.650	.637	.626
2	.615	.605	.596	.587	.579	.571	.564	.557	.550	.544
3	.528	.532	.526	.521	.517	.511	.506	.501	.497	.493

Diameters of leaden bullets from 1 to 39 in the pound, according to Sir Jonas Moor.

	0	1	2	3	4	5	6	7	8	9
0	0	1.690	1.341	1.172	1.064	0.988	0.930	0.883	0.845	0.812
1	0.784	0.760	0.738	0.719	0.701	0.685	0.671	0.657	0.645	0 633
2	0.623	0.612	0.603	0.594	0.586	0.578	0.570	0.563	0.556	0.550
3	0.544	0.537	0.532	0.527	0.521	0.517	0.512	0 507	0.503	0.498

The diameter of the muſket bores differ not above one fiftieth part from that of the bullet; for if the ſhot but juſt rolls into the barrel it is ſufficient. The government allows 11 bullets in the pound, for the proof of muſkets, and 14 in the pound, or 29 in two pounds, for ſervice: 17 for the proof of carabins, and 20 for ſervice; and 28 in the pound for the proof of piſtols, and 34 for ſervice.

As powder meaſures are uſeful in artillery, being more handy than weights, ſaving time, and are neceſſary in ricochet firing, we ſhall inſert here ſome experiments I made upon that ſubject in 1753, at the royal academy of artillery.

I. A cy-

I. A cylinder, whoſe axis and diameter were two inches each, contained 3 ounces and 3 grains, or 51 grains; and as ſimilar cylinders are as the cubes of their axis; if we ſay 51 grains are to 256 grains, or one pound, as the cube 8 of 2 inches is to the cube 40.156 of the diameter of a like cylinder holding one pound.

II. A cylinder, whoſe axis and diameter were 4 inches each, held 25 ounces and 10.5 grains, or 410.5 grains; whence 410.5 grains are to 256 grains, as the cube 64 of 4 inches is to 39.912, the cube of the axis of a cylinder holding one pound.

III. A cylinder, whoſe diameter and axis were 6 inches each, held 5 pounds 6 ounces and 6 grains, or 1382 grains. Hence 1382 : 256 : : 216 : 40.01 for the cube required.

IV. A two inch cube held 4 ounces and 1 grain, or 65 grains; and as 452 is to 355, ſo is the cube 8 of the axis to the content of the cylinder, which therefore is 51.05. Hence 65 : 256 : : 8 : 40 : 117, the cube of the axis.

V. A ſix inch cube held 6 pounds 13 ounces and 13 grains, or 1757 grains; ſo then 452 : 355 : : 1757 : 1379.944, or 1380, the content of the cylinder; and if 1380 : 256 : : 216 : 40.07, this fourth term will be the cube of the axis required. Hence a medium of theſe five experiments gives 40,053 cubic inches, whoſe cube root 3 42 will be the diameter of a cylinder holding a pound of powder.

From hence we may deduce the ſpecific gravity of powder. which is no more than the content of a cubic foot expreſſed in ounces. Now ſince 355 is to 452, as the content 16 ounces of the cylinder is to 20.372, the content of the cube of its axis, and the cube 40 of the axis is to the cube 1728 of 12 inches, or a foot, as 20.372 ounces to 880 ounces contained in a cubic foot of powder.

Sir *Jonas Moor* found by ſeveral experiments the diameter of a cylinder holding a pound of powder to be 3.165 inches.

Dia-

Diameters and heights of cylindric powder measures from 1 to 39 ounces, according to the author.

$\frac{z}{3}$	0	1	2	3	4	5	6	7	8	9
0	0	1.357	1.710	1.957	2.154	2.321	2.467	2.596	2.714	2.830
1	2.9[illegible]4	2.963	3.107	3.198	3.271	3.347	3.420	3.490	3.557	3.622
2	3.684	3.744	3.803	3.859	3 915	3.968	4.021	4.072	4.121	4.170
3	4.217	4.263	4.309	4.353	4.397	4.439	4.481	4.523	4.563	4.603

The logarithm of an ounce is .1326467; the other numbers are found, by adding one third of the logarithm of the number of ounces. Thus the number of 8 ounces is found by adding .3010300, one third of the logarithm of 8 to that of one ounce, which gives .4336767 for the logarithm of the number sought; which therefore is 2.714.

Diameters and heights of cylindric powder measures from 1 to 39 pounds, according to the author.

℔	0	1	2	3	4	5	6	7	8	9
0	0	3.420	4.309	4.932	5.429	5.848	6.214	6.541	6.824	7.114
1	7.368	7.606	7.830	8.041	8.243	8.434	8.618	8.794	8.963	9.126
2	9 283	9.435	9.583	9.726	9.865	10.00	10.13	10.26	10.38	10.51
3	10.63	10.74	10.86	10.97	11.08	11.16	11.29	1[illegible].45	11.50	11.60

Diameters

Diameters of cylindric powder measures, when the diameter is to the axis as 2 to 3, according to the author.

℥	0	1	2	3	4	5	6	7	8	9
0	0	1.181	1.491	1.710	1.880	2.027	2.155	2.268	2.371	2.472
1	2.554	2.588	2.714	2.788	2.857	2.924	2.988	3.049	3.164	3.164
2	3.218	3.271	3.322	3.371	3.420	3.466	3.513	3.557	3.600	3.643
3	3.684	3.724	3.764	3.807	3.841	3.878	3.915	3.951	3.986	4.021

℔	0	1	2	3	4	5	6	7	8	9
0	0	2.988	3.764	4.308	4.743	5.109	5.428	5.714	5.961	6.215
1	6.436	6.644	6.840	7.024	7.201	7.368	7.529	7.682	7.830	7.972
2	8.109	8.242	8.372	8.496	8.618	8.736	8.849	8.963	9.068	9.181
3	9.286	9.382	9.496	9.583	9.679	9.769	9.863	10.06	10.05	10.13

These diameters are found, if those of the former tables be divided by 1.1447, the cube root of $\frac{3}{2}$.

As I look upon these experiments to have been made with great accuracy, this difference can proceed from no other cause, than that the grain of the powder was something finer in his time than at present. The changing the size of the grains, is attended with many inconveniences without the least advantage; for the powder measures made at one time are either larger or less than what they should be at another, whereby great mistakes are made in loading of pieces. Sometimes more, and other times less powder is used than intended; and to change them continually, is attended with expences,

pences, and cannot always be done abroad, where they have no conveniency to do it: such mistakes were made at *Minorca* some years ago, where the powder measure held 35 pounds instead of 30; and at the end of the season, the officer could not account for the spending so much more powder than he intended, till he found the mistake by examining the measure.

When the grains are made as large as we do at present, it happens that some of them are much smaller than others, and the small take fire sooner than the rest, by which the force of some is partly expended before the rest is fired, and consequently the total force is not so great as it would be, if the grains were nearly of the same size.

It has been imagined by some, that the large grained powder is stronger than the small: but Captain *Desaguliers* made some experiments with grained and mealed powder; both which carried the shot the same distance. It may be presumed, that powder was not grained at its first discovery, but in course of time experience shewed that it kept longer in grains than otherwise; for which reason this custom is followed by all nations, and is undoubtedly the best.

Diameters and heights of cylindric powder measures, holding from 1 ounce to 19, according to Sir Jonas Moor.

$\frac{2}{3}$	0	1	2	3	4	5	6	7	8	9
0	0	1.257	1.583	1.811	1.994	2.148	2.282	2.403	2 512	2.613
1	2.706	2.793	2.876	2.953	3.027	3 098	3.165	3.230	3.292	33.52

These diameters are in inches and decimals.

Diameters and heights of cylindric powder measures, holding from 1 to 19 pounds.

lb	0	1	2	3	4	5	6	7	8	9
0	0	3.165	3.988	4.565	5.024	5.412	5.751	6.054	6.330	6.583
1	6.890	7.039	7.245	7.442	7.628	7.805	7.975	8.138	8.295	8.391

This laſt table is conſtructed in this manner; multiply continually the cube 31.705, of 3.165, by the number expreſſing the weight of powder, and the product will be the cube of the diameter and axis of the cylinder ſought. Or thus, add continually .5003737, the logarithm of 3.165, to the third part of the logarithm of the number ſhewing the weight, then the ſum will be the logarithm of the diameter required.

Thus one third .2006866, of the logarithm of 4, being added to the logarithm .5003737, gives .7010603, for the logarithm of the diameter of a cylinder, holding 4 pounds of powder, which is 5.024 inches.

The diameter of a cylinder, holding an ounce of powder, is found by ſubtracting one third of .4013733, the logarithm of 16, from the logarithm .5003737, then the difference .0990004, will be the logarithm of the diameter required; which being continually added to one third of the logarithm of the given number of ounces, gives the logarithm of the diameter ſought.

As powder meaſures are more convenient, when their axis is longer than their diameters, we ſhall give the

Diameters of cylindric powder measures, when the diameter is to the height, as 2 to 3, according to Sir Jonas Moor.

oz	0	1	2	3	4	5	6	7	8	9
0	0	1.097	1.382	1.582	1.742	1.876	1.994	2.099	2.194	2.282
1	2.364	2.440	2.512	2.580	2.644	2.706	2.765	2.820	2.874	2.926

lb	0	1	2	3	4	5	6	7	8	9
0	0	2.765	3.483	3.988	4.389	4.728	5.024	5.289	5.530	5.751
1	5.957	6.149	6.330	6.501	6.664	6.819	6.967	7.104	7.241	7.325
2	7.505	7.628	7.749	7.863	7.975	8.085	8.191	8.204	8.396	8.495

These two laſt tables are conſtructed, by multiplying continually the diameter in the two former tables, by the cube root .873 of $\frac{2}{3}$, then the product will give the diameters of cylinders, holding the ſame quantity of powder, or elſe by adding——.0586971, the logarithm of .873, or the third part of that of $\frac{2}{3}$, to the logarithm .5003737, found above; then the ſum .4416766, being continually added to one third of the logarithm of the number expreſſing the weight, the ſum will be the logarithm of the diameter ſought.

For example, to find the meaſure that ſhall hold 28 pounds: the logarithm of 28 is 1.4471580, one third of which being added to the given logarithm .4416766, gives .9240626, for the logarithm of the diameter required, which therefore is 8.396 inches.

This rule is proved from the known property in geometry, that equal ſolids have their baſes and altitudes reciprocally proportional. Hence, if a expreſſes the diameter of the baſe or altitude, and x the diameter of the

the baſe of the cylinder required; then becauſe the diameter x of the baſe is to its altitude as 2 to 3 by ſuppoſition, the altitude will be $\frac{3}{2}x$; and hence, $a^3 = \frac{3}{2}x^3$, by the condition of the problem, or $\frac{2}{3}a^3 = x^3$; the cube root of which is $a\sqrt[3]{\frac{2}{3}} = x$.

In the ſame manner may be found the diameter of a cylinder, which is to its altitude in any other given ratio, ſuch as 1 to 2, or as 3 to 5.

As it is neceſſary that an artillery officer ſhould know how to compute the number of ſhot contained in a ſquare or oblong pile, finiſhed or unfiniſhed, we ſhall give here a method for finding the number of ſhot more general than that in our Elements of Mathematics, page 98, deduced from a moſt compendious principle.

INVESTIGATION *of a general rule for finding the ſums of ſeries's.*

If z expreſſes the number of terms of a ſeries, whoſe ſum can be expreſſed by the product of factors that are in an arithmetical progreſſion; to find the z or general term of that ſeries.

N. B. The general term of a ſeries is ſuch an expreſſion compoſed of a variable z and conſtant quantities, that when z is made equal to 0, 1, 2, 3, or 1, 2, 3, 4, it gives the firſt, ſecond, third, fourth term of that ſeries.

It is evident, that by diminiſhing the value of z by the common difference n of the factors, the ſum will be diminiſhed by the laſt term, and the difference between theſe two ſums will be the z or general term required.

Thus if $z . z+n . z+2n . z+3n$, be the ſum of any ſeries, by writing $z-n$ for z, we get $z-n . z . z+n . z+2n$: which ſubtracted from the firſt, gives $4n . z\ z+n . z+2n$; for the general term required.

N. B. The points between the factors ſignify multiplication.

 General

General RULE.

From the ſum of a ſeries, to find its gneral term; *multiply the ſum by the number of factors and the common difference, and ſtrike out the laſt factor.*

N. B. Whether the ſum is multiplied by a conſtant number, or the factors decreaſe or increaſe, the rule is the ſame.

Thus the ſum $a z$ gives a for a general term; $z . z + 1$ gives $2 z$; the ſum $z . z - 1 . z - 2$ gives $3 z . z - 1$, and $z . z + n . z + 2 n . z + 3 n$, gives $4 n . z . z + n . z + 2 n$.

General RULE.

From the general term of a ſeries to find the ſum of any number z of terms.

Increaſe the factors by one more factor, and divide by the number of factors thus increaſed, and by the common difference.

Thus the general term a gives $a z$ for the ſum, $a z$ gives $\frac{1}{2} a z . z + 1$; $z . z + 1$ gives $\frac{1}{3} z . z + 1 . z + 2$, and $z . z - n . z - 2 n$, gives $\frac{1}{4 n} z . z - n . - z - 2 n . z - 3 n$.

Obſerve, when the firſt value of z is 0, the factors muſt be of a decreaſing progreſſion; but if it is any number of an increaſing progreſſion, as examples will ſhew.

EXAMPLE I.

Let the ſeries be any arithmetical progreſſion as a, $a + n$, $a + 2 n$, $a + 3 n$, &c. whoſe general term is $a + z n$, when the values of z are 0, 1, 2, 3, and the ſum $a z + \frac{1}{2} n . z - z - 1$. of z terms. If 1, 2, 3, 4; then $a = n = 1$, and $\frac{1}{2} z . z + 1$, the ſum of z terms. If 5, 7, 9, 11, then $a = 5$, $n = 2$, and $5 z + z . z - 1$ or $z . z + 4$, the ſum of z terms.

Example II.

Let the series be the squares of an arithmetical progression, as aa, $\overline{a+n}|^2$, $\overline{a+2n}|^2$, &c. whose general term is $\overline{a+zn}|^2$ or $aa+2nz+nnzz$, and o, 1, 2, 3, the values of z: hence the sum of the two first terms is $aaz+nz.\overline{z-1}$, and since $zz=z+z.\overline{z-1}$, whose sum is $\frac{1}{2}z.\overline{z-1}+\frac{1}{3}z.\overline{z-1}.\overline{z-2}$, or $\frac{1}{6}z.\overline{z-1}.\overline{22-1}$, when reduced under the same denomination.

Therefore $aaz+nz.\overline{z-1}+\frac{1}{6}nnz.\overline{z-1}.\overline{2z-1}$, is the Sum of z terms of that series.

Thus if the series is the squares of the natural numbers 1, 2, 3, 4, then $a=n=1$, and $z+z.\overline{z-1}+\frac{1}{6}z.\overline{z-1}.\overline{2z-1}$, or $\frac{1}{6}z.\overline{z+1}.\overline{2z+1}$, when reduced under the same denomination.

If the series is 1, 9, 25, 49, that is the squares of the numbers 1, 3, 5, 7, 9, then is $a=1$, $n=2$, and $z+2z.\overline{z-1}+\frac{2}{3}z\overline{z-1}.\overline{2z-1}$, or $\frac{1}{3}z.\overline{2z+1}.\overline{2z-1}$, the sum when reduced. If $z=10$, then will 1330 be the sum of the 10 first terms.

Example III.

If ab, $\overline{a+1}.\overline{b+1}$, $\overline{a+2}.\overline{b+2}$, be the series, which is that of the horizontal range of a rectangular pile of shot, whose general term is $\overline{a+z}\,\overline{b+2}$, or $ab+\overline{a+b}\,z\times zz$, and o, 1, 2, 3, 4, the values of z; the sum is therefore $abz+\overline{a+b}.\frac{1}{2}z.\overline{z-1}+\frac{1}{6}z.\overline{z-1}.\overline{2z-1}$, by examp. II.

This series may be reduced to A.$\overline{2a+z-1}\times\overline{2b+z-1}+\frac{1}{3}\overline{z+1}.\overline{z-1}.x$ by $\frac{1}{4}z$. For $\overline{2a+z-1}$, multiplied by $\overline{2b+z-1}$, gives $4ab+\overline{2a+2b}.\overline{z-1}+\overline{z-1}.\overline{z-1}$, and $\overline{z-1}.\overline{z-1}$ added to $\frac{1}{3}\overline{z+1}.\overline{z-1}$, and the whole divided by 4 gives the first sum.

General RULE *for an incomplete pile.*

To twice the length and breadth of the upper surface, add the corner row less one.

To the product of these two numbers add one third of the product, the corner row less one by the corner row more one, and multiply the sum by one fourth of the corner row.

Thus, if the sides of the upper surface are 20 by 4, and the corner row 6;

Then the sum of 40 and 5, multiplied by the sum of 8 and 5, gives — — 585

One third of 7 multiplied by 5, gives — — $11\frac{2}{3}$

Then the sum $596\frac{2}{3}$ of these two products, multiplied by 6 and divided by 4, gives 895 for the number of shot contained in that pile.

CASE I.

When the pile is complete then $b=1$, and the sum A, becomes $3a+2z-1x$ by $\frac{1}{6}z.z+1$. Which gives this

General RULE *for a complete pile.*

To three times the upper row add twice the corner row less one.

Multiply the sum by the product of the corner row, by the corner row more one, and divide the product by 6.

If the upper row be 20, and the corner one 12; then 3 times 20, added to 23, gives — — — 83

Multiply 83 by 12, this product by 13, and divide by 6, which gives 2158 for the number of shot required.

CASE II.

When both a and b become unity, the sum A becomes $\frac{1}{6}z.z+1.2z+1$, which gives this

General

General RULE *for a complete square pile.*

Multiply the corner row by that row more one, multiply this product by twice the corner row more one, and divide by 6.

If the corner row be 50, then $\frac{1}{6}$ 50.51 . 101, or 25 . 17 . 101, gives 42925 for the number of shot required.

N. B. By dividing before the multiplication is performed, as we have done, and which is always possible, the operation becomes shorter.

CASE III.

When $b = a + 1$, the series becomes $a\,\overline{a+1}$, $\overline{a+1}.\overline{a+2}$, and if each of these terms be divided by 2, it will be that of a triangular pile, and because $b = a + 1$, the sum A divided by 2, gives $\overline{2a+z-1} + \overline{2a+z+1} + \frac{1}{3}\overline{z+1}.\overline{z-1} \times$ by $\frac{z}{8}$.

General RULE *for triangular incomplete piles.*

To twice the side of the upper row, add the corner row less one, and the corner row more one.

To the product of these two numbers, add one third of the product, the corner row less one by the corner row more one, and multiply the sum by one eighth of the corner row.

If the side of the upper row be 26, and the corner 20; then twice 26 added to 19, gives 71; twice 26 added to 21, gives —— —— —— 73

And 71 multiplied by 73, gives —— —— 5183

One third of 21 multiplied by 19 —— 133

The sum 5316, multiplied by 20, and divided by 8, gives 13290, for the number of shot contained in the pile.

CASE IV.

When *a* is unity, the ſum in the laſt caſe becomes $\frac{1}{6}z.z+1.z+2$, which gives this

General RULE *for a complete triangular pile.*

Multiply the baſe by the baſe one more, this product by the baſe more two, and divide by 6.

If the baſe be 40, then 40 by 41, by 42, and the product divided by 6, gives 11480 for the number of ſhot contained in this pile.

Theſe are all the different rules that can be given upon that ſubject, and to ſave the reader the trouble of computation, we ſhall inſert here four large tables containing the number of ſhot in 2912 complete piles. The firſt column of theſe tables contains the number of the corner rows, and the upper horizontal line the number of the upper ranges. The number of ſhot in a pile is againſt the number of the corner row, and under that of its upper range. The laſt column contains the number of ſhot in a triangular pile, oppoſite to the number of its corner row in the firſt column.

PART II.

Conſtruction of GUNS.

WHAT has been ſaid in the Introduction, with regard to the proper length of pieces, and the properties of different chambers in mortars, will enable us to form ſome general conſtructions of pieces, deducted from experiments and theory, and therefore leſs liable to exceptions, than thoſe hitherto given by others, which

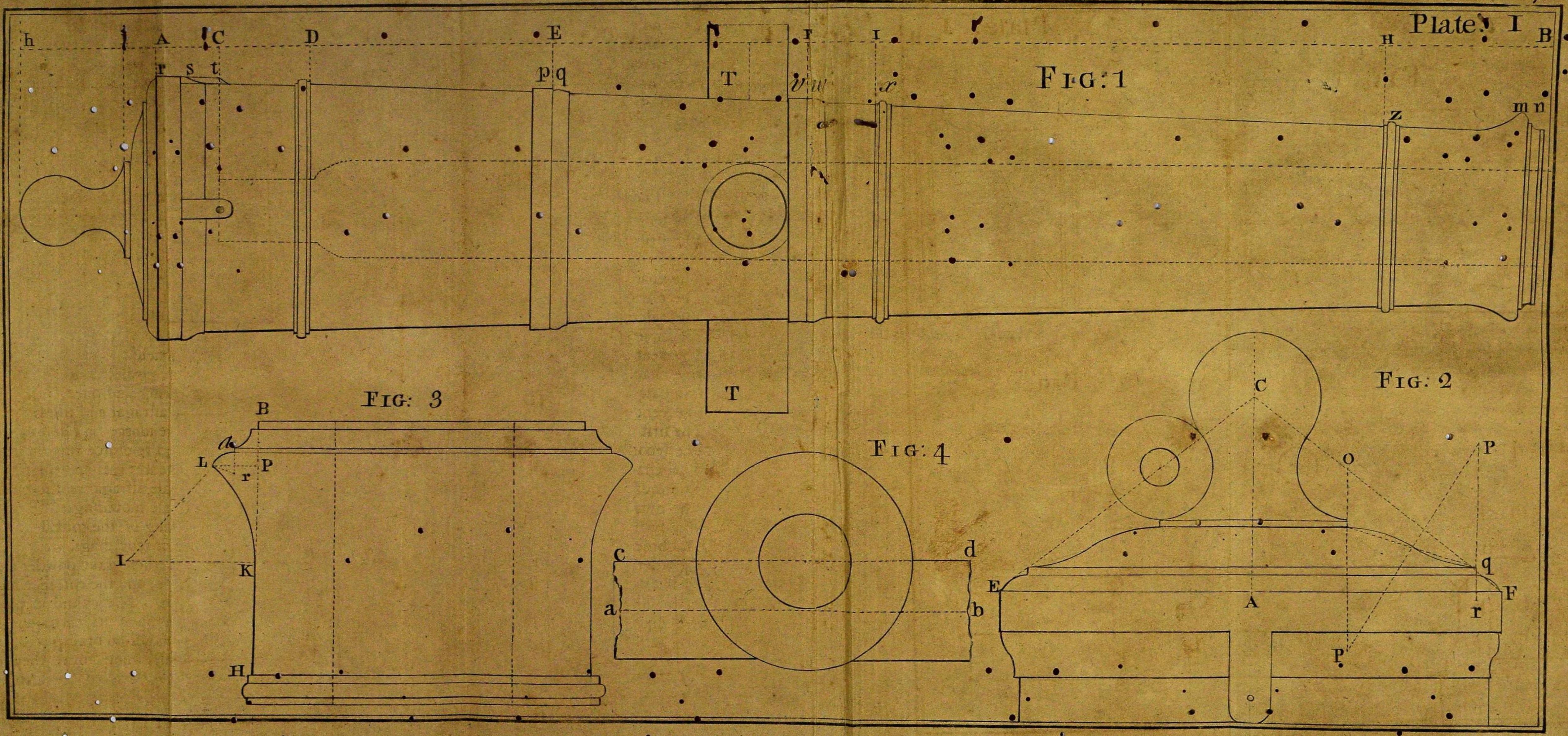


Plate I
Fig: 1
Fig: 2
Fig: 3
Fig: 4

which ſeem to have no other foundation, than the particular fancy of the contriver, and generally a bare imitation of others. Before we proceed any farther, it is neceſſary to give the names of the ſeveral parts of which pieces are compoſed, in order that what is ſaid may be clearly underſtood.

Names of the ſeveral parts of a gun.

Plate I. Fig. I.

A B. The length of the gun.
A E. The firſt reinforce.
E F. The ſecond reinforce.
F B. The chace.
H B. The muzzle.
A h. The caſcable.
A C. The breech.
C D. The vent field.
F I. The chace girdle.
r. s. The baſe ring and ogee.
t. The vent aſtragal and fillets.
p q. The firſt reinforce ring and ogee.
v w. The ſecond reinforce ring and ogee.
x. The chace aſtragal and fillet.
z. The muzzle aſtragal and fillets.
n. The muzzle mouldings.
m. The ſwelling of the muzzle.
A i. The breech mouldings.

The vacant cylinder, wherein the powder and ball are lodged, is called the Bore, and the entrance of the bore, the Mouth of the Gun. The cylindric parts T, by which the gun is fixed upon its carriage, are called Trunnions; and the handles on braſs pieces, are called Dolphins, from the fiſh whoſe form they repreſent. The diameter of the bore is called the Caliber of the Piece. Laſtly, the difference between the diameters of the ſhot and the bore, is called the Windage of the Gun.

REMARKS

REMARKS.

The length of a gun is always reckoned from the hind part of the base ring, or beginning of the cascable, to the extremity of the muzzle. The second reinforce begins at the same circle where the first ends; and the chace at the same circle where the second reinforce ends.

The first reinforce includes the base ring, ogee next to it, the vent field, vent astragal, and first reinforce ring; the second reinforce, the ogee next to the first reinforce ring, and the second reinforce ring; and the chace, the ogee, next to the second reinforce ring, the chace girdle and astragal, the muzzle and astragal. The trunnions and dolphins are always placed on the second reinforce; the first, so as the breech part may weigh something more than the muzzle part, to prevent the piece from kicking up behind when it is fired; which it will always do so long as the center line is placed below that of the piece, as has been the custom ever since their invention. On the contrary, the dolphins are so placed, that when the gun is suspended thereby, the breech and muzzle parts may equally poise.

The artillerists here differ in the names of several parts; not one of them can tell precisely how far the muzzle reaches, nor the cascable; for some call the swelling the muzzle, others the breech mouldings, the cascable, and say, that the button is a separate part by itself, and not included in the cascable.

As no one has hitherto attempted to write upon Artillery in *English*, and to fix the names, it is no wonder that the practitioners differ, since they have no guide to go by. The only thing we could do, was to fix the names of the parts in the most convenient manner to their construction, and to prevent confusion. We have called the part from the beginning of the muzzle astragal to the mouth, the Muzzle; because that astragal deriving its name from the muzzle, it seems therefore that

that the muzzle ſhould reach ſo far. As to the caſcable, it cannot properly be determined otherwiſe than we have done; ſince it is commonly ſaid, that a piece is of ſuch a length, excluſive of the caſcable; it agrees likewiſe with what general *Armſtrong* ſays in his Conſtruction, as well as the diſtinction made by the founders and practitioners.

Formerly pieces were diſtinguiſhed by the names of Sakers, Culverins, Cannon, and Demi-cannon; but at preſent their names are taken from the weight of their ſhot; as for example, a 12 or 24 pounder, carries a ball of 12 or 24 pounds weight.

As moſt conſtructions of authors agree in general, and differ only in ſome particulars, we ſhall give that of general *Armſtrong*'s, formerly ſurveyor-general of the ordnance, which appears to me leſs deficient than any that have hitherto been given, which are

General RULE *for braſs and iron guns.*

The length of the gun being divided into 7 equal parts; the length of the firſt reinforce A E, is two of theſe parts; the ſecond E F, one, and a diameter of the bore; ſo that the chace F B is four of theſe parts, wanting a diameter of the bore.

The diſtance from the hind part of the baſe ring, to the beginning of the bore, that is, the breech A C, is always equal to the thickneſs of the metal at the vent. The trunnions T, are always a caliber in length, and as much in diameter, clear of the ſecond reinforce ring, and placed in ſuch a manner, that a right line drawn through their centers touches the lower part of the bore, as in the fourth figure, where that line is marked a, b, and paſſing through the third diviſion; that is to be three ſevenths from the hind part of the baſe ring. The length of the caſcable A h, is always two calibers and a quarter.

These

Theſe diviſions are in general made by all nations, only the trunnions are placed half a caliber more backward by the *French* *.

General dimenſions of braſs guns.

The caliber of the gun is divided into equal parts	16.
The thickneſs of metal at the baſe ring from the bore, is	16.
At the end of the firſt reinforce ring,	14.5
At the ſame place, for the beginning of the ſecond reinforce,	13.5
At the end of the ſecond reinforce,	12.5
At the ſame place for the beginning of the chace,	11.5
At the end of the chace or muzzle, the mouldings excluded,	8.

MOULDINGS.

Breadth of the baſe ring,	1.5 inches.
Breadth of the ogee, next to the baſe ring,	2.
From the ogee to the fore part of the aſtragal, a caliber.	
The fillets of the aſtragal, are each	.28
The aſtragal, or half-round	.56
Total of the aſtragal and fillets,	1.12
At the firſt and ſecond reinforce ring, the fillets are	.25
Breadth of the firſt and ſecond reinforce rings	1.25
The ogees next to theſe rings,	1.5
The fillets at the muzzle,	.25

* This figure does not anſwer to the following conſtructions, but it is ſufficient to ſhew the reader how to proceed, according to the given dimenſions.

The

The muzzle ogee, in a 12 pounder and upwards, is 1.25 inches; but in a 9 pounder and under it is an inch only. The chace girdle and aſtragal is one caliber. The ſpace from the mouth of the gun to the muzzle aſtragal, in an 18 pounder and upwards, is equal to a diameter of the ſecond reinforce ring; but in a 12 pounder and under, it is equal to the diameter of the firſt reinforce ring.

The riſing of the mouldings at the firſt and ſecond reinforces, is an eighth of an inch; and the riſing of the baſe ring is determined by laying a ruler to the extremities of the firſt and ſecond reinforce mouldings. The ſwelling of the metal at the muzzle is always equal to the diameter of the ſecond reinforce ring.

Cascable.

From the hind part of the baſe ring, to the fore part of the fillet next to the bottom, $\frac{1}{3}$ of a caliber.

From the fore part of the fillet next to the button, to the centre of the button, one caliber.

From the hind part of the baſe ring, to the hind part of the fillet, between the two * ogees, $\frac{1}{6}$ of a caliber.

Diameter of the fillet next to the button, 1.5 caliber.

Diameter of the neck, $\frac{3}{4}$ of a caliber.

Diameter of the button, ſomething more than a caliber, it is ſix inches in a 24 pounder.

It muſt be obſerved, that the ſhell at the vent is 3 inches broad, and reaches from the baſe ring, to within a quarter of an inch of the vent aſtragal, leaving that ſpace for the eaſe of turning, and the vent is a fifth part of an inch.

* The reader muſt obſerve, that general Armſtrong made two ogees, though there is but one marked here.

General

General dimensions for iron guns.

The caliber of the gun is here divided into 14 equal parts.

The thickness of metal at the vent from the bore, is — — —	16 parts.
At the end of the first reinforce —	14.5
At the beginning of the second reinforce,	13.5
At the end of the second reinforce, —	12.5
At the beginning of the chace, —	11.5
At the end of the chace or muzzle, —	8.

As to the mouldings, and the rest of the dimensions, they are much the same as before, only the diameter of the vent is here one fourth of an inch, without any reason given for it.

The lengths of the guns, according to this gentleman, were as follows; the 32 pounder brass, 10 feet; the 24 and 18 pounders, 9.5 feet; the 12 pounder, 9; the six, 8; the three, 7; and the 1.5 pounder, 6 feet.

The iron 32 pounder, 9.5 feet; the 24 and 18 pounders, 9; the 12, eight; the 9, seven; the 6, six and half; and the 3, four and half feet.

Some of these dimensions have been altered since for others, grounded upon no better reason than the former.

The reader may easily perceive the perplexity of these constructions, arising from the different scales that are used without the least necessity. That the greatest part of the mouldings should have the same dimensions, from a 3 pounder to one of 32, appears contrary to reason, and especially contrary to the rules of architecture; from whence they have been taken. To make as many mouldings in iron guns, which are rough and not turned, as in brass ones, is another blunder; but these are trifles in regard to the absurdities in general committed in these constructions; which cannot better be discovered, than by examining all the parts separately, each in their order.

Length

Length of guns.

If the continual changing the length of pieces be confidered it will appear evident, that practice alone is infufficient to determine that which is the beft; and if the experiments hitherto publifhed on that account are examined with fome attention, it will be found, that for want of proceeding from proper principles, the refult of them is erroneous and inconclufive.

For the greateft part of them were made to difcover fuch a length as fhould carry the fhot fartheft, without mentioning what the charge fhould be; believing that the greater the velocity of the fhot is, the more its execution would be: but it has been found on the contrary by experience, that a velocity which is fufficient to carry the fhot juft through a wall, does more execution than one that is greater. Others, fuch as Mr. *Dumetz*, and the late general *Armftrong*, endeavoured to find the beft length of a piece, when loaded with two thirds of the fhot's weight; and to attain which, Mr. *Dumetz* made ufe of different calibers, which had all the fame length, *viz.* 10 feet, and he found that the 24 pounder carried its fhot fartheft.

Now, what can be concluded from thefe experiments? Nothing more, as I conceive, than that 10 feet is a better length for a 24 pounder, loaded with that charge, than for any fmaller caliber: but it does not determine, that this length is fuch, as to carry the fhot fartheft of any other; for we are not certain, whether one of 8 or 9 feet long would not be better than this, fince no trial has been made to fhew that it would not. Befides, we are as much at a lofs as ever, to know what are the beft lengths for fmaller or greater calibers.

From the experiments made by general *Armftrong*, it was concluded, that 9.5 feet was the beft length for a 24 pounder, though that of 9 feet produced the greateft range.

As these pieces were all of the ſame weight, it is plain, that ſome of them were too ſtrong in proportion to their length; and if they had been reduced to a proper ſize, their ranges might probably have changed: but ſuppoſe this is in reality the beſt length for a 24 pounder, we are nevertheleſs in the dark with reſpect to the other calibers. So that the moſt that can be made of theſe experiments, is, that the length of the 24 pounder has been determined nearly, with regard to the charge made uſe of.

But it has been found ſince by experiments, that 8 pounds of powder are ſufficient for a 24 pounder, when it is to make a breach; for the *French* uſed no more all the two laſt wars in all their ſieges. This being the caſe, all former experiments are exploded, and conſequently others ought to be made, in order to determine the beſt length for that charge.

But are we certain that this charge is the beſt that can be uſed? I think by no means; for we have found, that one fourth of the weight of the ſhot is ſufficient for field-pieces, and even a leſs one. And we are not certain, that the ſame charge might not do in battering pieces, or on board of ſhips; ſo that new trials ſhould be made firſt, to know the beſt charge before the lengths of the pieces can be determined.

The making ſmall calibers longer in proportion than great ones, is attended with many inconveniences and of no advantage, ſo far as I can judge, ſince there is no neceſſity for their carrying as far as the heavy ones, which I ſuppoſe was the reaſon the artiſts went upon; but this ſuppoſition is erroneous; becauſe there is but one certain length that is better than any other, greater or leſs, as we ſhall ſhew; and therefore they may as well be too long as too ſhort.

Another inconveniency attends this practice, which is, that ſome of theſe pieces weigh above twice more than they ought to do, according to the moſt heavy conſtruction, whereby their carriage from place to place becomes

becomes more troublesome, and the expence at least one third more.

Lastly, when the lengths of pieces are not proportioned to the diameters of their shot, the experiments made with one caliber will not be of any use to any other, nor the dimensions used; and therefore as many experiments must be made as there are different calibers, as well as so many different constructions, in order to make them equally good and strong; and I may add, that this practice is the principal reason that so little improvement has been made in the construction of pieces, and that so much confusion is met with in them; whereas, if they are all the same number of diameters long, one general construction will be sufficient for all those made of the same metal; and when the dimensions of any one piece have been determined by experiments, it will serve for them all; the pieces will be similar, and their weights in the same proportion to that of their shot. Finally, the construction of all kind of pieces will be so short and easy, as that they may be comprehended in a few leaves, as will be seen hereafter.

Since then neither practice, nor any theory hitherto published, no more than the experiments made in *England* or *France*, have as yet furnished us with any satisfactory rule to proceed by, and yet Artillery cannot be improved without it; we shall endeavour to shew here, both from theory and some unexceptionable experiments, that there is a certain length of a gun better than any other longer or shorter, whereby it will carry its shot the farthest possible. For general *Williamson* of the Artillery made many experiments at *Minorca*, which are related in the introduction; whereby it appears that an eighteen pounder which weighed 3900, and length 9 feet, carried farther than another eighteen pounder that weighed 5100, and was 11 feet long, when equally loaded, and with the same angle of elevation; it was found likewise, that nine pounds of powder was the best charge, and carried the shot farther than any other. From

whence it appears, that the greatest length of this caliber ought not to exceed 9 feet; but whether it might not be less has not yet been tried.

Now as 9 feet is 21 diameter of the shot nearly, and it is very probable that all calibers, proportionably long and charged, will produce similar effects, we may draw this conclusion, *that the length of pieces which carry their shot farthest does not exceed* 21 *diameter of its shot*; and *that their best charges are equal to half the weight of their shot.*

This will receive no small degree of certainty from what we have proved in the appendix to this work, page 122, where we have shewn, that the greatest velocities which cannon shot of different calibers can have, are always proportional to their diameters; and as their lengths ought to be in proportion to their charges, and they are proportional to the diameters of their shot, the length must therefore likewise be proportional to the diameters of their shot.

We have likewise proved in the same page, that the greatest velocities of projected bodies have certain limits which they cannot exceed, let the force that acts upon them be what it will; which confirms that part of the experiments with respect to the best charge.

Now since the greatest velocities of projected bodies are proportional to their diameters, the largest caliber will therefore carry their shot farthest. Consequently, the question of finding the length of a piece, so as to produce the greatest range, depends on its caliber, its length, and on its charge, which we have here determined.

As these experiments are the best and only ones that ever were made on Artillery, as far as I have seen or know, and agree exactly with the theory we have given in the appendix, so we may affirm this theory to be the best and only one grounded upon true and unexceptional principles, and that all others hitherto published are

without

without foundation; and therefore all the concluſions drawn from them erroneous.

Though it may be convenient on ſome particular occaſion to have guns which carry their ſhot as far as poſſible, yet in common practice this rule is not to be followed; for on board of ſhips theſe long and heavy guns would not anſwer ſo well as ſhorter and lighter, becauſe ſhort guns are eaſier loaded, require leſs room for the recoil, and are more expeditious in action; and ſince ſhips come ſo near together in action as they do at preſent, the long ranges are intirely uſeleſs: beſides, the charge of half the weight of the ſhot is too much, and ought never to be uſed, one third at moſt is quite ſufficient, and perhaps leſs, does more execution, and heat the guns leſs: all theſe advantages ought not to be neglected.

The length of battering pieces ought to be ſuch, as to enter into the embraſures ſo far, as that the blaſt of exploſion does not deſtroy them in a day's firing; in that caſe they may be repaired again at night, becauſe it is impoſſible to prevent the effect of the blaſt intirely: for which reaſon all calibers, not exceeding a 24 pounder, may be 21 diameters long, but thoſe above cannot be ſo long without inconveniencies; but the charges ſhould never exceed one third of the ſhot's weight, becauſe it has been found by experience that this charge is ſufficient, and perhaps leſs would be better.

It muſt be obſerved, that guns ſhould never be loaded with more powder than is juſt ſufficient to produce the deſired effect, which a ſkilful commander can or may always diſcover in practice; by which the guns will not be heated more than is neceſſary, and they may be fired longer without receiving much damage.

What has been ſaid in reſpect to battering pieces may be applied to garriſon ones; only the beſt charges may be given them on particular occaſions, as at the beginning of an attack to oblige the enemy to begin his approaches as far as poſſible, or in a place ſituated near

the ſea, or a navigable river, to prevent ſhips from coming too near.

The field pieces ſhould have the beſt length and charges, in order to annoy the enemy at the greateſt diſtance, excepting the battalion guns, which ſhould be ſhort and light, that they may advance as well as retire as quick as the army. From whence follows this

General RULE.

That the length of guns ought to be determined from their particular uſes.

Thickneſs of METAL.

It is an univerſal cuſtom in *Europe* to make the guns with reinforces; that is, they are, as it were, made of three fruſtrums of cones joined together, ſo as the leaſt baſe of the former is always greater than the greateſt of the ſucceeding one, whereby the metal breaks off in two places on a ſudden, as the reader has ſeen in the conſtruction of pieces given here before. But ſince powder acts uniformly and not by ſtarts, it is hard to judge from whence this ridiculous cuſtom has ariſen, which ſeems to be as old as the invention of guns; and nothing but the ignorance of the effects of powder has been the cauſe of its being handed down to our time. Our veneration for old cuſtoms is ſo great, that whoever attempts to make any change is looked upon with contempt, let his reaſons be ever ſo plain and good; this I know too well by experience.

Yet I ſhall freely communicate whatever I think to be an improvement and uſeful to the public; let the conſequence be what it will, I ſhall do my duty. Since then powder acts gradually and not by ſtarts, there ſhould be no breakings off in the metal; and we have ſhewn in the remark after Theor. IV. that the piece ſhould be cylindric, from the baſe ring to the end of the

the charge, and from thence, by the nature of the explosion, a curve line bending inwards quite to the mouth of the piece: but as the construction of the curve is not very easy, and differs in the main but very little from a right-line, by making the part between the end of the charge and the mouth conical, it will be sufficiently exact for practice.

When pieces were loaded with two thirds of their shots weight, the thickness of metal was then at the vent equal to the diameter of the shot; but since there is no occasion to load pieces with more than half that weight, the thickness of metal ought to be less; for which reason the present light 6 pounders are only the two thirds of the diameter of the shot thick, and their length 15 diameters: the same thickness is given to the 24 pounders, and their length is but 12 diameters; and as this thickness has been found sufficient by many trials, when the charge and length remain the same, there is no reason to make them stronger.

The strength given to iron guns is certainly more than required, supposing the charge no more than one third of the shot's weight; this has been found true by some, whose thickness at the vent was equal to the diameter of the shot, and half that thickness at the mouth.

Vent.

The common method of placing the vent is within about a quarter of an inch from the bottom of the chamber or bore: yet it is imagined, that if the vent was to come out at the middle of the charge, the powder would be inflamed in less time than in any other case. But notwithstanding that this appears so visible, and seems to be demonstrable, yet I have found the contrary, to the great surprize of the spectators. I had two mortars, the chamber of one cylindric, the diameter of the base one inch, and the axis two; the chamber of the other

concave; each of these chambers had two vents, one at the bottom, and the other in the middle, and contrived in ſuch a manner, that one could be ſcrewed up, whilſt the other ſerved to fire; and I found always the range of the ſhell greater, when the lower vent was uſed, than when the powder was fired by the middle one. The ſame thing was tried by colonel *Deſaguliers* and me, with different cylindric chambers, ſome of which were three or four times the diameter of the baſe in length.

This being fact, it remains now to know, whether the ſame would do in mortars of a larger ſize, or in guns; for I muſt own, that after theſe trials, and ſome others of a ſtill more extraordinary nature, which have been mentioned in the introduction, I can ſcarcely believe any thing relating to the effect of gunpowder, but what has been found true by a ſufficient number of experiments.

BORE.

The windage, or difference between the diameters of the ſhot and the bore, is not the ſame in *England* as abroad. Suppoſe the diameter of a ſhot divided into 20 equal parts, then the diameter of the bore is 21 of theſe parts; the *French* ſuppoſe the diameter of the ſhot divided into 26 parts, and the diameter of the bore to be 27; what the proportion is in *Holland* and other parts of *Germany* I do not know; but it is evident, that the leſs windage there is, the truer the ſhot will go; and having leſs room to bounce from one ſide to another, the gun will not be ſpoiled ſo ſoon; for which reaſon I ſuppoſe, in the following conſtructions, the diameter of the ſhot to be divided into 24 equal parts, and make the bore 25, which is a medium between the *Engliſh* and *French* method. This we do not ſo much in order to differ from others, as on account of the convenient ſcale it affords, to conſtruct not only guns thereby, but alſo their carriages, as will be ſeen hereafter.

The

The *French* make little chambers in their 16 and 24 pounders, of one third of a caliber long, and as much in diameter; by this means they ſay the metal becomes thicker at the vent; and prevents its ſpoiling ſo ſoon. But as chambers are much more advantageous in other reſpects, we ſhall conſtruct ſome hereafter, ſo as to have all the advantages that can be had.

Some are for making the bottoms of the bore conical, others ſpherical; and laſtly, ſome quite flat; but I can find no reaſon to prefer one way before another, excepting the conveniency there may be in adapting the cartridges in a more eaſy manner to their form.

TRUNNIONS.

The method of placing the trunnions ſo that their axis touches the lower ſurface of the bore, as is practiſed all over *Europe*, is ſo abſurd, that it is amazing no author or artiſt has thought proper to change it; the only reaſon I ever heard given for this practice, was, that by this means they were ſtronger fixed to the gun, and of conſequence would not break off ſo ſoon as in any other place. As inſignificant as this reaſon is, it ſerves however to defend that old eſtabliſhed cuſtom.

But to ſhew the abſurdity of it; ſuppoſe A B to repreſent the center line of the bore, and C D the diſtance of the center line of the trunnions from that of the bore. Now becauſe when the piece is fired, the exploſion acts againſt the breech B, and makes the piece recoil, but being fixed to the carriage by the trunnions, endeavours to turn about the point D, whereby it preſſes alſo upon the coins under the breech B, where they by their elaſti-

city

city repel it upwards, and its weight brings it down again. The piece therefore acquires a pendulous motion about the center D, which causes the coins to fly off, changes its direction, and shakes the carriage with great violence, and often breaks it to pieces.

In long pieces this effect is not so sensible as in short ones; and though carriages generally break in their centers, yet the cause has never been attributed to the wrong situation of the trunnions; not even after the many accidents of that kind which have happened lately: for a short and light 24 pounder was tried at *Woolwich*, to know whether they might not be as useful in action as the light 6 pounders; but every time it was fired, it broke its carriage to pieces. From these accidents, and its recoiling more than the heavy pieces, they were rejected as useless, without thinking in the least that both inconveniencies might easily be remedied.

The piece stood upon a platform of stone quite level, which is not, nor ever has been, practised on any occasion whatever; for in the field they are placed upon the rough ground without any platform; and as the recoil is never so great in such a situation, as upon a level stone platform, this objection is to no purpose: and that this is fact beyond dispute, appears from the trials made at the same time with light 6 pounders, which recoiled likewise in an extraordinary manner, notwithstanding they are found in real service not to do so.

In a siege, when batteries are erected, the platforms are made of wooden planks, raised behind, more or less, according as it is necessary, to prevent the pieces from recoiling farther than is convenient to reload them. And since this may be done at pleasure, without the least inconvenience, the rejecting them on that account is frivolous and absurd.

To prevent these pieces from breaking their carriages is easy, if we dare break through old customs, by making the axis of the trunnions to pass through the center line of the bore, as may be seen in our construc-

tions

tions hereafter. The pretence of their breaking off from the piece is taken away, by making ſhoulders to them; beſides, this objection is only imaginary, ſince it has never been tried.

What we have ſaid upon this head is likewiſe confirmed by practice in howitzes, which, being fixed to their carriages in the ſame manner as guns, are properly nothing elſe than ſhort guns with chambers; for their trunnions are placed in the manner we propoſe, and, when fired, acquire no other motion than a backward one, without ſhaking in the leaſt the carriage; nor did their trunnions ever ſuffer.

Mouldings.

As they are made by way of ornament only, they depend chiefly on the maker's fancy; it muſt however be obſerved, that they ſhould be plain and ſimple, and ſuch as are uſed in architecture, from whence they have been borrowed; the metal ſhould be projected as little as can be, that the piece may lie cloſe on the carriage: the mouldings of our mortars are oddly jumbled together, without any order or judgment; and thoſe of our iron guns are more numerous than is conſiſtent with reaſon, for they have fillets on both ſides the firſt and ſecond reinforce rings, which are not uſed in braſs pieces; and as theſe mouldings are not turned in iron, they appear ridiculous, and more ſo in ſwivel guns, which have as many as thoſe of the largeſt caliber.

Muzzle.

The ſwelling of the metal at the muzzle ſeems to have been made merely to make the pieces look graceful, or perhaps to appear of a larger caliber to an enemy at a diſtance than they really are. When they are too heavy, the piece is liable to bend at the neck when heated with much firing, which makes it either break

or

or bend, and so become useless. Some are of opinion, that the metal should be as high at the muzzle as at the base ring, that the visual ray over the metal may be parallel to the center line of the bore, which they imagine to be necessary for laying or pointing the piece in a proper manner; but those who are for this practice are very little acquainted with real service: for as the shot descends in its flight by the force of gravity, the piece must be laid higher than the object to be hit; so that when the metal is equally high before and behind, the object is hid intirely by the thickness of the metal, and consequently the piece can never be laid true; whereas if the height of the metal be less at the muzzle than at the breech, the elevation of the piece, when pointed at the object, will answer the descent of the shot at a certain distance, and the skill of the gunner will be sufficient to make a proper allowance when the object is either farther or nearer.

Cascable.

They are made of various figures; sometimes like a bunch of grapes, or as the heads of different kinds of animals: the *French* distinguish their calibers by the different forms of the cascables; but as this is expensive when they are well carved, and looks paltry when not well done, the manner of making them quite plain, with a button and a few breech mouldings, as we do here, seems in my opinion much neater, and is less expensive. It is true, that the distinguishing the different calibers is very proper; but this may be done in another manner, more agreeable to the sight, and cheaper.

Line of Direction.

Formerly pieces were made with a cavity upon the base ring, and a button upon the highest part of the muzzle, whereby they were directed in the same manner

as

as fowling-pieces are; but how this line came to be left off in latter times I cannot tell; for to find the center line of a piece every time it is to be fired with a plummet or an inſtrument, as is the cuſtom, is very tedious, uncertain, and unmaſterly; for as it is impoſſible to turn the outſide of a piece true to the bore, conſidering the bluntneſs of the tools and the heavineſs of the engine, the center line can never be found to any tolerable degree of exactneſs, by an inſtrument applied on the outſide of a piece; and when the ſhot does not hit the mark, the gunner is at a loſs to know, whether it is owing to his want of ſkill, or to this line not being rightly marked; whereby it is impoſſible he ſhould be able to form a right judgment how to direct the piece.

But when the line of direction is marked on the piece in the aforeſaid manner, and the ſhot does not hit the mark, he knows how to rectify the miſtake, becauſe the line remains always the ſame, whether it be marked right or not, which I have ſeen many times. It is ſaid, that the platforms are never rightly level, and if one wheel of the carriage ſtands higher than the other, the line of direction becomes uſeleſs; but I can find no reaſon for not laying the planks level when the platform is made, ſince I always have ſeen a level uſed; and this may even be done ſufficiently exact by the eye without a level, ſince a ſmall trifle, either on one ſide or other, cannot cauſe any great error in the laying of the piece; and in a field engagement, where no batteries are made, it is of no ſignification, whether the piece points a little to the right or left, provided it is not too high or too low.

CALIBERS.

The choice of calibers depends on two conſiderations, *viz.* they ſhould never be leſs than thoſe of other nations; becauſe in an engagement by land or ſea, the larger ſhot have always the advantage; and their diameters

meters ſhould have a ſenſible difference to diſtinguiſh their ſhot with eaſe; otherwiſe it may happen in an engagement, when men are generally in ſome confuſion, that the one will be taken for the other, as has happened to my knowledge, whereby the piece becomes unſerviceable, till the ſhot ſticking in it, has been blown out again; which ſometimes cannot be done without rendering the piece unſerviceable.

As the conſtruction of pieces, as well as that of their carriages, ought to depend on the diameter of their ſhot, methinks they ſhould be expreſſed by whole numbers as much as can be, or at leaſt by ſome eaſy fractions. Thus they ſhould be expreſſed by 3; 3.5; 4; 4.5; 5; 5.5; 6 inches; which anſwer nearly to a 4, 6, 9, 13, 18, 24 and 31 pounders. And as the diameter of a 9 pound ball is 4 inches, and may ſerve in a manner as a ſtandard to make the reſt by, I am ſorry to ſee that this caliber has been rejected lately in braſs cannon.

This is what we thought neceſſary to premiſe before we enter upon the conſtruction of pieces, to ſatisfy the reader, that they are the reſult of a well aſſerted theory, and of ſuch reaſons as ought to be well conſidered beforehand; but whether they will ſatisfy artiſts prejudiced in favour of the moſt abſurd, old eſtabliſhed cuſtoms, is what time will ſhew: the ſubject is of ſo great an importance to the nation, that it deſerves to be well examined before-hand, and proper experiments made before any change is introduced; for which reaſon I ſubmit theſe my endeavours to ſerve the public to the judgment of my ſuperiors.

General CONSTRUCTION *for braſs battering pieces.*

Plate I. Fig. I.

Let the length A B, of the piece, be 18 diameters of the ſhot; divide that diameter in 24 equal parts for a ſcale,

ſcale, whereby all the reſt of the dimenſions are determined. Make the diameter of the bore equal to 25 of theſe parts; from the hind part A of the baſe ring, to the fore part D of the vent aſtragal ſet off 40 parts; make the thickneſs of metal taken from the bore at A and D, equal to 18 parts, that is, three quarters of the ſhot's diameter, and 9 parts, or half that thickneſs at the mouth; then the lines drawn through theſe points will determine the figure of the gun, which therefore is cylindric from A to D, and conical from thence to the mouth.

The center line of the trunnions croſſes the center line of the bore at right angles, and at a diſtance of three ſevenths of the total length A B of the gun, from the hind part A of the breech; their diameter is 18 parts, as well as their length, free from the projection of the ſecond reinforce ring; the ſecond reinforce E F, is always two thirds of the firſt A E; the breech A C is 16 parts, the chace girdle F I, 14; the muzzle H B, the tenth part of the total length of the gun, which is here 43 parts, and the diameter of the ſwelling, m, of the muzzle is 6 parts diſtant from the mouth.

The breadth of the baſe ring and ogee next to it are each 6 parts; the firſt and ſecond reinforce rings, and the ogees next to them, 5, the aſtragals and fillets 4; the cavetto at the mouth 2.5, and the fillets one each.

The baſe ring projects the metal by two parts, the firſt and ſecond reinforce rings by one, or rather leſs; the fillets of the aſtragals by one half, and the round part is deſcribed from a center placed in the outline of the piece. There is a circular ſhoulder about the trunnions, whoſe diameter exceeds that of the trunnions by 6 parts, and projects even with the ſecond reinforce ring.

CASCABLE. Fig. 2.

The diſtance from the hind part A, of the baſe ring, to the center C, of the button, is 27 parts, the radius of the button 9, the breadth of the quarter round 2, the ogee 5, and the fillets one each. From the center C of the button, draw lines to the extremity of the baſe ring E, F, in which find the center O, ſo as the arc deſcribed meets the arc of the button in the line C F, and touches the ſecond fillet: theſe arcs will determine the neck; the line O p, drawn through the center O, parallel to C A, will determine the ſecond fillet, and C F, the firſt.

To deſcribe the ogee, join the extremities n, q, of the fillets; through the point q, draw the line r p, parallel to O n, produced; in theſe two lines find the centers p, ſo as the arcs deſcribed through the points n q, meet in the middle of the line n q: the arc which determines the quarter round, is deſcribed from a center r, in p, q, produced ſo as to meet the extremity F, of the baſe ring within one part. The ſhell is 6 parts broad, and the diameter of the vent a fifth part of an inch.

MUZZLE. Fig 3.

Take the line B K, equal to twenty parts, and erect the perpendicular I K, after having made L P, equal to 6 parts, the center I, is to be found ſo as the arc deſcribed, through the point K, ſhall meet the point L; and if through the point a, at 4 parts diſtant from H B, the line a r, be drawn perpendicular to L P, the center r, is to be found ſo as the arc deſcribed through the point L, may meet the extremity of the fillet a. The cavetto is no more than a concave quarter round.

It has been found by experiments, that when pieces have chambers, they require a leſs charge than they would do otherwiſe; for which reaſon I would make a chamber in all pieces of 24 pound ball and upwards, whoſe diameter ſhould be two thirds the diameter of the bore,

bore, and length equal to that diameter. Such as is represented in the first figure. Although this chamber contains but one ninth part of the shot's weight of powder, yet the effect it produces is nearly equal to that of a fourth part; which is sufficient in large pieces.

Whatever faults there may be found with the particulars of this and the following constructions, it cannot, however, be denied but this is the true method whereby artillery pieces should be made; for since architecture has its certain rules whereby to construct the several parts of a column from its diameter, there is no reason why the parts of a piece should not be determined in the same manner.

To find the weight of metal.

The square of 43, the diameter of the muzzle without mouldings, — —	1849
The square of 61, the diameter at the vent astragal, — — — —	3731
The rectangle, or main plan of these diameters, 43 and 61, — — —	2623
The sum of these three products added, —	8193
Which multiplied by one third of 392, the length D B, — — —	1070552
The square of the diameter 61, multiplied by 40, the length A D, — —	148840
Four times the cube of 18, for the trunnions, cascable, and mould, — —	23328
The sum of these last three products added,	1242720
The square of the bore 25, multiplied by its length 416, — — —	260000
The difference between these two last sums,	982720
The square of the diameter is to the area of the circle, as 452 to 355, — —	771826

 These

Theſe are cubic parts of the ſhot's diameter, divided into 24 equal parts: and as a cubic foot of gun metal weighs 459 pounds, according to our tables, or 192 cubic inches 61 pounds; the laſt ſum reduced in this proportion gives 245215.

But the cube of 24, the diameter of the ſhot, is to the cube of 4, the diameter of a 9 pound ball, as 216 to unity, ſo is 245215 to 1135 pounds, the weight of a 9 pounder; and if this number be divided by 9, we ſhall have 126 pounds of metal for every pound of the ſhot's weight. Conſequently the weight of the ſhot of any gun, according to this conſtruction, multiplied by 126, and the product divided by 112, gives the weight of the gun.

Length and weight of battering pieces.

Old Pieces.

Calib.	Length.	Weight.
6	8 : 0	19 : 0 : 0
9	9 : 0	25 : 0 : 0
12	9 : 0	29 : 0 : 0
18	9 : 6	48 : 0 : 0
24	9 : 6	51 : 0 : 0
32	10 : 0	55 : 2 : 7
42	9 : 6	61 : 2 : 10

New Pieces.

Calib.	Length	Weight.
12	6 : 7	13 : 2 : 0
18	7 : 6	20 : 1 : 0
24	8 : 4	27 : 0 : 0
32	9 : 2	36 : 0 : 0
36	9 : 6	40 : 2 : 0
42	10 : 0	47 : 1 : 0
48	10 : 6	54 : 0 : 0

The lengths of pieces are in feet and inches; old guns of the ſame caliber are not always of the ſame length, nor of the ſame weight; theſe given here are thoſe moſt commonly uſed at preſent; but for what reaſon the 32 pounder is longer than the 42 is only known to the maker.

Remarks

Remarks on this construction.

We have ſhewn in the Introduction, that the guns ſhould be cylindric as far as the charge reaches, and from thence conical to the mouth; and therefore the conſtruction is conformable to the theory: we have likewiſe ſhewn, that the center line of the trunnions ought to paſs through the center line of the bore; for when it is lower, as has hitherto been the cuſtom, the carriages are deſtroyed in a ſhort time; the diſtance of the trunnions from the breech is the ſame in both, and we found it likewiſe to be right by computation: the length of the 36 and 42 pounders is agreeable to that commonly given to battering pieces; and ſince both theſe calibers weigh leſs than the old 24 pounders, they may be uſed inſtead thereof, as well as the 48 pounder, which weighs very little more than ſome 24 pounders, eſpecially as a breech is much ſooner made by large calibers than by ſmall ones; and that they are ſtrong enough we are certain, ſince our preſent field-pieces, whoſe ſtrength is to that of theſe in the proportion of 8 to 9, have been found by repeated experiments, to bear any firing whatever; and they need not be loaded but with one fourth of the ſhot's weight, when they are made without chambers, ſince the force of a 32 pounder, loaded with 8 pounds of powder, is greater than that of a 24 pounder loaded with 8 pounds, in the proportion of the weights of their ſhot; that is, in proportion of 4 to 3; and the force of a higher caliber is ſtill greater.

It is true that theſe new pieces would recoil more than the old, if they were loaded with the ſame charges, which is not the caſe; beſides, it may be eaſily prevented, by allowing a greater ſlope to the platform. Conſequently the pieces, according to this conſtruction, have greatly the advantage over the old ones.

Conſtruction of iron battering and garriſon pieces.

Let the length A B be 21 diameters of the ſhot, divide that diameter into 24 equal parts as before, make the diameter of the bore 25; from the hind part A of the baſe ring, to the fore part D of the vent aſtragal, ſet off 48 parts; make the thickneſs of the metal, taken from the bore at A and D, equal to 25 parts, and 12 at the mouth B.

The center line of the trunnions croſſes the center line of the bore at right angles, at the diſtance of three ſevenths of the total length of the gun, that is nine diameters from the hind part A of the breech: their diameter is 24 parts, as well as their length, free from the progreſſion of the ſecond reinforce ring; the firſt reinforce 9 diameters and 3 parts; the ſecond 5 diameters and 9 parts; the breech A C, 24 parts; the muzzle H B, 50; the chace girdle F I, 16; the diameter of the ſwelling at the muzzle is 6 parts diſtant from the mouth; and the reſt as before.

By the ſame manner of computation as before, I find two hundred weight of metal for every pound of the ſhot's weight. Hence we have the following,

Iron battering and garriſon pieces.

Caliber.	Length.	Weight.
3	4 : 10	6 : 0 : 0
4	5 : 4	8 : 0 : 0
6	6 : 1	12 : 0 : 0
9	7 : 0	18 : 0 : 0
12	7 : 8	24 : 0 : 0
18	9 : 0	36 : 0 : 0
24	9 : 8	48 : 0 : 0
32	9 : 8	56 : 0 : 0

Obſerve

Obſerve, that the 32 pounder is but 19 diameters long; the thickneſs of metal at the breech 24, and 11 at the muzzle. Experience has ſufficiently ſhewn in this laſt war, that iron guns ſtand much better, in making a breech, than the braſs; for the latter have failed in all the ſieges they were uſed.

I can affirm, that a hundred and a half of metal is ſufficient for one pound of the ſhot's weight, provided the guns are made of good virgin ore: and one ſhould think it would be the intereſt of the nation, to make uſe of the beſt that is to be found in the country for that purpoſe.

Beſides, a ſet of 6, 7, 12, 18, 24, 32 of braſs pieces, weigh 22700 weight, which, at 130 *l.* *per* ton, coſt 1475 *l.* 10 *s.* and the ſame ſet of iron weighs 19400, a ton coſts 16 *l.* and the whole ſet 155 *l.* 4 *s.* So that 9 ſets of iron coſt no more than one of braſs.

Conſtruction of braſs pieces for ſhips.

As long guns are very inconvenient on board of ſhips on account of the difficulty in loading them, we ſhall ſuppoſe the length A B to be 15 diameters of the ſhot, which diameter being divided into 24 equal parts, as before, and the diameter of the bore being likewiſe 25 parts; the diſtance AD is 40 parts; the breech AC 18; the thickneſs of the metal at A and D is 20, and 10 at the mouth B; the reſt of the conſtruction is the ſame as before; only the diameter and length of the trunnions are 20 parts each.

By the ſame manner of computing the weight of metal as before, we ſhall have 124 pounds of metal for every pound of the ſhot's weight; which gives the following table.

Brass ship guns.

Caliber.	Length.	Weight.
3	3 : 6	3 : 1 : 17
6	4 : 4	6 : 2 : 14
9	5 : 0	10 : 0 : 0
12	5 : 6	13 : 1 : 3
18	6 : 4	20 : 0 : 0
24	7 : 0	26 : 2 : 7
32	7 : 6	35 : 1 : 17
36	7 : 10	40 : 0 : 0
42	8 : 4	46 : 2 : 0
48	8 : 6	53 : 0 : 14

Remarks on this construction.

In this construction we have not considered the strength so much as the weight, on account of the recoil; for should that be too great it might be attended with great inconveniency, such as tearing the tackle. But when these guns are loaded with one fourth of the shot's weight, if there are no chambers made, the recoil will be but little greater, or perhaps no more than that of old guns loaded with half of the shot's weight: this being the case, there is not the least reason to make pieces so heavy as at present, nor so long: for if it be considered that ships may carry 12, 18, 24, 36, 42, 48 pounders of this new construction, instead of 6, 9, 12, 18, 24, and 32 pounders of the present, and at the same time carry less burthen; it must appear to every rational person, what advantage such a ship must have above an enemy's

enemy's of the ſame rate. To illuſtrate this by an example, we ſhall give here a liſt of the guns, length and weight, which are on board the *Royal George*.

Pr.	Num.	Length.	Weight.	Total
42	28	9 : 6	61 : 2 : 10	1820
24	28	9 : 6	51 : 0 : 0	1428
12	28	9 : 0	29 : 0 : 0	812
6	16	8 : 0	19 : 0 : 0	304

Total 4366 or 218.3 tons.

A new ſet of guns.

Pr.	Num.	Length.	Weight.	Total.
42	28	8 : 4	46 : 2 0	1302 : 0 : 0
32	28	7 : 6	35 : 1 17	991 : 3 : 1
24	28	7 : 0	26 : 2 7	743 : 3 : 21
18	16	6 : 4	20 : 0 0	320 : 0 : 0

Total —— 3357 : 2 : 22
Total in tons — 167.8
Difference —— 50.5

It muſt be obſerved, that inſtead of 28 pieces of 42 pounders (formerly taken from the *French*) which are at preſent on board, the ſame number of ours are to be put in their place.

Hence it appears, notwithſtanding, that there are 28 pieces of 32 pounders in the new liſt, inſtead of 28 twelve pounders, and 16 eighteen pounders inſtead of the ſame number of ſixes; yet the difference between the total weights is 50.5 tons, an object too conſiderable not to be obſerved. Beſides, the new guns being ſhorter than the old, they may be fired much faſter.

That the ſtrength of theſe guns is ſufficient, appears from the trial of 2 twelve pounders made for admiral *Keppel*; they were loaded with 12 pounds of powder each time,

time, and ſtood the proof, without receiving any damage; and I may venture to ſay, that they would ſtand any number of firings with the common charge.

General conſtruction for iron ſhip guns.

Let the length of the piece be 15 diameters of the ſhot; the diameter of the bore 25 parts of the ſhot's diameter divided into 24, as before; the diſtance A D, 40 parts; the breech A C, 24; the thickneſs of metal at the vent 24, and half that thickneſs at the mouth; the diameter and length of the trunnions 24 each, and the reſt of the conſtruction the ſame as before.

By the ſame way of computing as before, we ſhall find 140 pounds of iron, or a hundred and a quarter, for every pound weight of the ſhot: ſuppoſing that 108 cubic inches of caſt iron weigh 29 pounds, according to our table of ſpecific gravities.

Iron ſhip guns.

Old pieces.

Calib.	Length.	Weight.
3	4 : 6	7 : 1 : 7
4	6 : 0	12 : 2 : 13
6	7 : 0	17 : 1 : 14
9	7 : 0	23 : 2 : 2
12	9 : 0	32 : 3 : 3
18	9 : 0	41 : 1 : 8
24	9 : 0	48 : 0 : 0
32	9 : 6	53 : 3 : 23
42	10 : 0	55 : 1 : 12

New pieces.

Calib.	Length.	Weight.
3	3 : 6	3 : 3 : 0
6	4 : 4	7 : 2 : 0
9	5 : 0	11 : 1 : 0
12	5 : 6	15 : 0 : 0
18	6 : 4	22 : 2 : 0
24	7 : 0	30 : 0 : 0
32	7 : 6	40 : [illegible] : 0
42	8 : 4	52 : 2 : 0
48	8 : 6	60 : 0 : 0

Remarks

Remarks on this construction.

The making iron pieces in such a manner as not to be heavier than is necessary, nor yet too weak, so as to be in any danger to break when fired briskly for some time, is of the greatest importance, insomuch as all our ships, one or two excepted, are provided therewith; for by making them too heavy the ships cannot carry so many large calibers as they otherwise might, which is agreed by the best judges to be a great disadvantage; if, on the other hand, they should be so weak as not to bear a brisk firing, the bursting of a piece in an action might create such a confusion as to cause the loss of the ship. But to prove beyond doubt that no danger can be apprehended from guns made according to this construction, provided the iron is good (such as that of the *Carron* company) appears from the trial of 2 three pounders made for lord *Egmont*; for they both stood the ordnance proof loaded with three pounds of powder, and I am certain they would have stood if they had been loaded with double that charge. There was also made 2 six and 2 twelve pounders for Monf. *De Malo*, the *Portuguese* envoy; and they stood their proof, and would have done it, if they had been loaded with much greater charges than the weight of their shot. Now since all the calibers are proportionally strong, according to their charges, the one being found strong enough by practice, all the rest must be so too. Secondly, we have a great many 6 and 9 pounders that were cast formerly, and which have been used a great while, and are less thick at the muzzle astragal than the new ones; this being an undeniable fact, proves again that the new are of a proper strength. The reason that the present guns are so much heavier than the new, is owing to their greater length; besides the charges of powder have hitherto been greater than was necessary, and the strength of the pieces has, or ought to have been

been made in proportion. With regard to the length of these new pieces, they are such as are conceived by some of the best sea officers to be much more convenient than if they were longer, on account of the rope rammer they are obliged to use; for in long pieces, if the rope is hard and stiff, it is bent with great difficulty, and if not, will scarcely suffice to ram the shot home.

Guns of a new construction used in the several men of war.

Num. of guns.	Weight of old.	Weight of new.	Num. of ships.	Weight of old number	Weight of the new number
100	4367. 3	2556. 0	5	21838. 3	12780
90	3537. 3	2001. 0	9	31839. 3	18009
80	3108. 3	1827. 0	7	21761. 1	12789
74	3091. 0	1840. 2	32	98912. 0	58896
70	2997. 0	1796. 2	10	29970. 0	17965
64	2543. 3	1305. 0	23	58506. 1	30015
60	2177. 3	1185. 0	30	65332. 2	35550
50	1881. 1	1035. 0	19	35743. 3	19665
44	1365. 2	705. 0	8	10924. 0	5640
40	1234. 2	312. 2	9	11110. 2	2812
36	963. 3	450. 0	7	6746. 1	3150
32	956. 2	435. 0	28	26782. 0	12180
28	593. 2	285. 0	23	13650. 1	6555
24	531. 3	255. 0	12	6381. 0	3060
20	421. 2	191. 1	15	6322. 2	2869

Total of the Weights —— —— 445820 : 241935
Difference —— —— —— 20388500 or 10194$\frac{1}{4}$ tons.
Difference of the expences —— 163108 l.

If to this we add the difference 26321 l. between the brass guns of the *Royal George* and the same set of iron, we get 189429 l. for the difference between the expences of the old and new set. And if the number of guns on board of the sloops and those in the garrisons, as well as those which serve in the field, it may perhaps amount to as much more.

Hence

Hence every ſhip may carry very nearly double calibers of theſe new guns to thoſe of the old ones, and that with ſafety, and be leſs burthened at the ſame time, as has been fully proved: the great advantage of ſuch a change muſt be plain to all ſuch as are concerned in naval affairs. I muſt obſerve one thing more, that the ſmall charge we propoſe may appear inſufficient in calibers under a 24 pounder; but when it is conſidered, that when ſhips come to a proper diſtance, the ſmall ſhots have as much chance to penetrate the ſhip as the large, though their effect is leſs in proportion; but at a great diſtance the reſiſtance of the air is greater in proportion as the diameter diminiſhes, as Mr. *Robins* has rightly obſerved.

But as all commanders make, or ought to make a point of it, to come cloſe to an enemy before they begin to fire, there is no reaſon to fear but that theſe ſmall calibers are as uſeful as any others.

Number

Number and caliber of guns on board the ſeveral men of war.

Old Eſtabliſhment.

N°	42	32	24	18	12	9	6	4
100	28		28		28		16	
90		26		26	26		12	
80		26		26		24	4	
74		28		28		18		
70		28		28		14		
64			26		26	12		
60			24		26		10	
50			22		22		6	
44				20		20	4	
40				20		20		
36					26		10	
32					26		6	
28						24		4
24						22		2
20					10		10	

New Eſtabliſhment propoſed.

N°	48	42	32	24	18	12	9	6
100	28		28	28		16		
90		26	26	26		12		
80		26	26		24	4		
74		28	28		18			
70		28	28		4			
64			26	26	12			
60			24	26		10		
50			22	22		6		
44			20		20	4		
40			20		20	4		
36				26		10		
32				26		10		
28				24		4		
24				22			2	
20				10		10		

The firſt column contains the number of guns which the ſhips carry, according to the preſent eſtabliſhment; the numbers in the firſt horizontal line expreſs the calibers uſed on board of the men of war; and the number of each ſort are under them oppoſite the number the ſhips carry.

Conſtruction

Construction for light field pieces.

Let the length A B of the piece be 14 diameters, the diameter of the shot divided into 24, and the bore 25 as before; the thickneſs A C of the breech 14, the diſtance A D 39; the thickneſs of metal at the vent A D 16, and 8 at the mouth; the diameter and length of the trunnions each 16 parts, and the reſt of the conſtruction as in the firſt.

A ring of metal is caſt under the caſcable in theſe light pieces, as is ſeen in figure the ſecond, which ſerves to faſten the head of a ſcrew, that is uſed inſtead of coins to raiſe the piece by: this ring is deſcribed from the ſame center, and with the ſame radius as the neck; the diameter of the hole to receive the bolt is 5 parts, and the thickneſs of the ring is 4 parts.

By the ſame way of computing the weight of metal as after the firſt conſtruction, we find about 85 pounds of metal for every pound of the ſhot's weight, which gives the following dimenſions.

FIELD PIECES.

Preſent.

Calib.	Length.	Weight.
3	3 : 6	2 : 3 : 10
6	4 : 6	4 : 3 : 10
12	5 : 0	8 : 3 : 8
24	5 : 6	16 : 3 : 13

New.

Calib.	Length.	Weight.
3	3 : 3	2 : 1 : 2
6	4 : 1	4 : 2 : 5
9	4 : 8	6 : 3 : 8
12	5 : 1	9 : 0 : 10
18	5 : 10	13 : 2 : 16
24	6 : 5	18 : 1 : 5

From

From whence it appears, that the weights of the new conſtructed pieces nearly agree with thoſe uſed at preſent; the lengths of the 3 and 6 pounders new are leſs, and thoſe of 12 and 24 ſomething more than the lengths of the preſent. We have hitherto uſed but the four calibers marked above, and even the 12 and 24 very little, becauſe it has been found that theſe pieces, placed on a level platform, and loaded with one-fourth of the ſhot's weight of powder, recoil too much: yet as platforms are never made upon any occaſion without a ſlope, and in an engagement are placed upon turf, and the advantage of the ground is or may be taken, the firing theſe pieces upon a level platform made of ſtone is not an experiment to be depended upon.

Theſe light 18 and 24 pounders may ſerve in private expeditions for battering pieces, eſpecially where the road is very bad, and no heavy pieces can paſs, and yet battering pieces are required; which is the caſe where a fort or any other poſt is to be taken; for no leſs calibers are eſteemed ſufficient to make a breach, or induce the commander to ſurrender. There have been much lighter pieces made not many years ago, as a 6 pounder weighing but three hundred and a half, and which carried its ſhot very well with a pound and a quarter of powder; but it is imagined that they are attended with inconveniencies in real uſe, for which reaſon they have been rejected.

Conſtruction of iron garriſon pieces.

Let the length of theſe pieces be 18 diameters of the ſhot, and the reſt of the conſtruction be the ſame as that of iron ſhip guns: then by a like computation as before, we find $172\frac{2}{3}$ pounds of iron for every pound of the ſhot, and from thence we get the following dimenſions.

IRON

IRON GARRISON PIECES.

Calib.	Length.	Weight.
3	4 : 2	4 : 2 : 12
6	5 : 3	9 : 1 : 0
9	6 : 0	13 : 3 : 12
12	6 : 7	18 : 2 : 0
18	7 : 6	27 : 3 : 0
24	8 : 4	37 : 0 : 0
32	9 : 2	49 : 2 : 18
42	10 : 0	64 : 0 : 0

As the 32 pounder weighs about the ſame, and is nearly the ſame length as the old 24 pounder, it may well ſerve upon the ſame occaſion. As to the lengths and weights of the other calibers, I imagine them ſuch as are proper for the uſes they are commonly applied to. The 42 pounder may alſo ſerve near the ſea, or in harbours, to prevent enemy's ſhips from paſſing by, with more advantage than 24 and 32 pounders, which are chiefly uſed at preſent upon thoſe occaſions.

But if ſome of the ſmaller calibers ſhould be thought too ſhort, according to the preſent practice, they may be lengthened ſo much as neceſſary, without changing any of the other dimenſions, which do not depend on the length.

Having given general conſtructions for the ſeveral ſorts of braſs and iron cannon, which are neceſſary upon different occaſions by land or ſea, in the moſt plain and eaſy

easy manner we could think of (which none have yet done) and as these constructions are grounded on the most plausible reasons, supported by theory and practice, it is hoped our endeavours will be of use to the public, as expences are considerably lessened. For if the great quantity of metal required in all the guns necessary to the nation, and the vast number of horses now used in the field be considered, and that according to our construction above one-third will be saved, as likewise a proportional number of horses, one would imagine these advantages sufficient to induce the directors of these affairs to examine well our scheme, and to make proper trials, in order to be convinced whether what is here proposed is of any real advantage or not; at the same time guarding against the crafty insinuations of ignorant artists, who find fault with improvements merely out of a selfish vanity, without judgment or knowledge.

As we propose to make chambers in all guns above an 18 pounder, it may be objected, that the difficulty of loading them will prevent their use; but as a rammer may be contrived so, as to load these pieces as easy as others, the only difference being to put the powder in cartridges, which is more than recompensed by saving almost half of it; besides, the pieces will not be heated so soon, and consequently they may be fired much oftener without any danger of being damaged. When all these advantages are well considered, it will be found that chambers in large cannon is an improvement not to be neglected.

We must observe one thing more before we leave this subject, which is, that as we make the diameter of the bore but one 24th part larger than that of the shot (whereas the common practice is to make it one 20th part more) if the bores of the new constructed guns are made as usual, they will be something lighter than what we have marked them in the preceding tables. But as a shot goes much truer when it just fits the bore, and does less damage to the gun, by not bouncing from one side

ſide to the other, it is to be hoped that they will be made in the manner we propoſe.

It is true that ſome artillery officers ſay, that the windage of a gun ſhould be equal to the thickneſs of the ladle; becauſe when it has been loaded for a while, the ſhot will not come out without being looſened thereby, in order to unload it; and when this cannot be done, it muſt be fired away, and ſo loſt; but as the windage of a 9 pounder, according to our conſtruction, is .166 of an inch, this is conceived a ſufficient thickneſs for a ladle, and thoſe of a higher caliber become ſtill thicker in proportion. But ſuppoſe this thickneſs is not ſufficient, the loſs of a ſhot is a mere trifle in reſpect to the advantage got thereby; beſides, as there is always a wad before the ſhot, I do not ſee that any duſt or dirt can get into the piece; and therefore when the muzzle is lowered, the ſhot will roll out of courſe.

There is another advantage in theſe general conſtructions, which is, that the diameters of the ſhot's being marked on braſs rulers at full length, and divided into 24 equal parts, they will ſerve as ſcales to draw the draughts in full lengths for the uſe of the founders and the carriage-makers, whereby the patterns may be made with great eaſe and exactneſs.

PART III.

Conſtructions of MORTARS *and* HOWITZES.

MORTARS are a kind of ſhort cannon of a large bore, with chambers. Their uſe is to throw hollow balls filled with powder, called *ſhells*; which falling upon any building, or into the works of a fortification, burſt, and their fragments deſtroy every thing within reach. *Carcaſſes* are alſo thrown out of them, which are a ſort of ſhells with five holes, filled with

pitch and other combuſtible matters, in order to ſet buildings on fire; and ſometimes baſkets full of ſtones, the ſize of a man's fiſt, are thrown from them upon an enemy, placed in the covert way in the time of a ſiege.

Mortars are diſtinguiſhed here chiefly by the diameter of the bore. For example, a ten inch mortar is that the diameter of whoſe bore is ten inches; there are however ſome ſmall ſorts, as coehorns and royals; the name of the firſt is derived from that of the inventor.

Sea mortars, or thoſe placed on board of ſhips, are longer and much heavier than the land. There is beſides another ſort, called howitzes, of a *German* invention, which differ from the former, in having their trunnions placed nearly in the middle, and being mounted upon carriages like travelling gun-carriages.

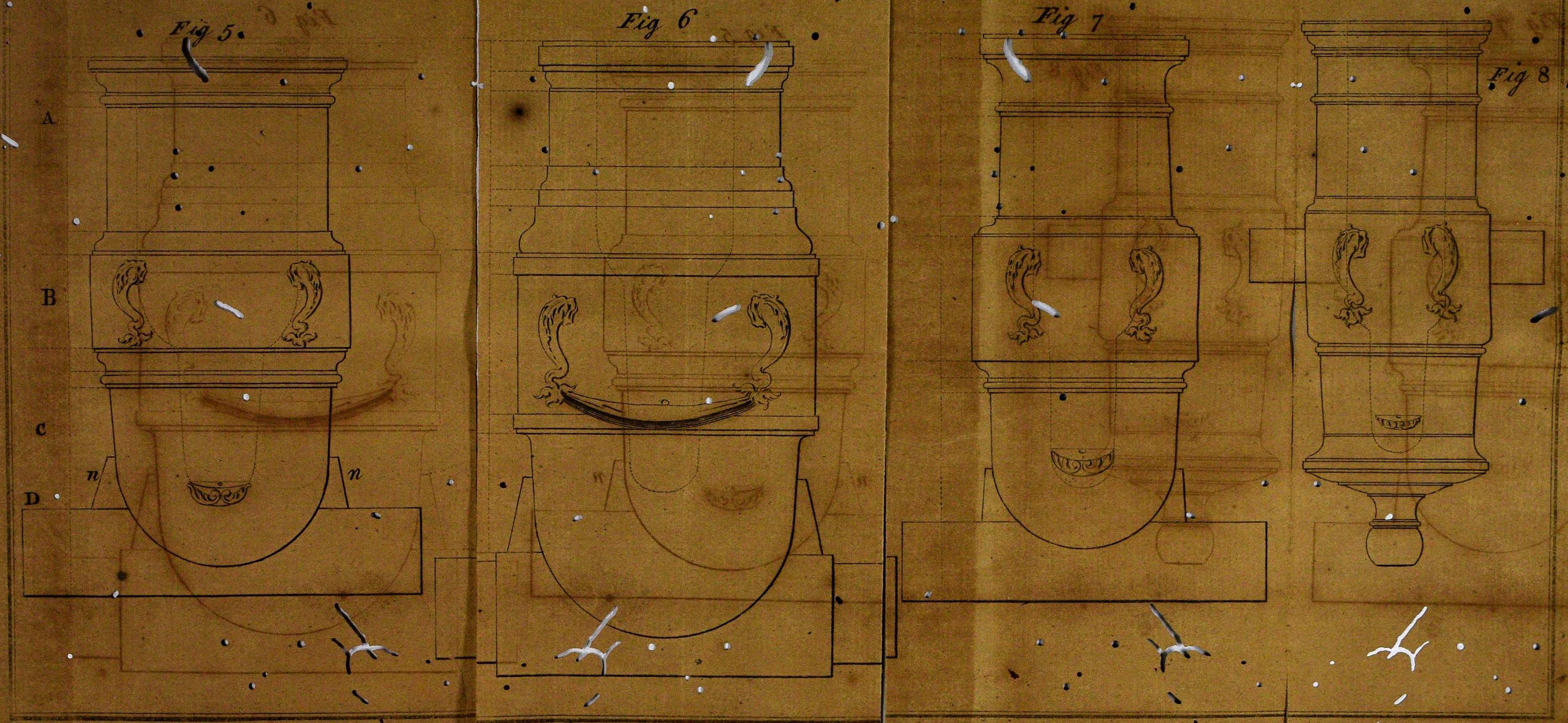
Plate II. Fig. 5.

The principal parts of a mortar are on the outſide the chaſe A, the reinforce B, the breech C, and the trunnions D. In the inſide, the part where the ſhell is lodged, is the bore; and the part where the powder is lodged, called the chamber. The parts *n n*.

The figure of the chamber is made variouſly by different nations; the *Spaniards* uſe chiefly the ſpheric; the *French* the conic, cylindric, and the bottled or concave; the *Engliſh* make them in the form of a fruſtum of a cone. Each nation has its reaſons, good or bad, to prefer their make before that of others; but whoever conſiders theſe different forms in an impartial manner, and the reaſons given by authors for adhering to one preferable to others, will find, that nothing is leſs determined upon true principles or experiments, than the proportions of the ſeveral parts of a mortar; we ſhall therefore begin to give ſome tables of their dimenſions, and afterwards examine the different parts ſeparately, as we have done in guns, in order that the reader may diſtinguiſh their perfections and imperfections.

Dimenſions

P. II



Dimensions of the brass land mortars now in use. Fig. 5.

Diameter of the bore — —	13	10	8	5.8	4.6
Total length of the mortar — —	44	33	25.5	16.5	13.5
From the mouth to the reinforce —	15.25	10	8.5	4.75	4.2
Length of the reinforce — —	8.75	8.1	5	5	3.9
Length of the trunions from end to end	32.5	26	20	12	9.2
Diameter of the trunions — —	7.15	6.3	5	2.75	2.15
Length of the bore — —	24	18	13	8.5	7.
Length of the chamber — —	12	7.8	7.75	4.5	3 7
Greatest diameter of the chamber —	6.6	4.5	4	3	2.7
Least diameter of the chamber —	6	3.6	3.4	2.4	1.4
Diameter of the muzzle ring —	21	15.15	11.2	8	6.4
Breadth of the muzzle ring — —	1.1	.8	.6	.7	.5
Breadth of the astragals and fillets —	1.25	1.0	.75	0	0
Distant from the muzzle ring —	1.5	1.0	1.0	0	0
Diameter near the muzzle astragal —	18.1	13.2	10	6.9	5.6
Diameter near the reinforce —	18.1	13.2	10.0	6.9	5.6
Diameter of the reinforce — —	21	15.15	15.1	8	6.4
Breadth of the ogees — —	1.5	1.0	1.0	0	0
Diameter behind the breech astragal —	18.1	13.2	9.8	6.9	5.9
Chamber contains powder — lb.	9 : 1 : 8	4 : 0 : 0	2 : 0 : 10	1 : 0 : 10	0 : 8 : 0
Weight of the mortar — — C.	25 : 0 : 0	10 : 2 : 18	4 : 0 : 20	1 : 1 : 0	0 : 3 : 0
Weight of the shell when filled — C.	1 : 2 : 25	0 : 3 : 2	0 : 1 : 17	0 : 0 : 13	0 : 0 : 7
Shell contains powder — — lb.	9 : 4 : 8	4 : 14 : 12	2 : 3 : 8	1 : 1 : 8	0 : 8 : 0

N. B. The extremity of the bore is made round, and formed by an arc, whoſe radius is equal to that of the bore, and terminated by the lines which form the chamber: the bottom of the chamber is ſemicircular, the outſide of the metal is determined by a circular arc, deſcribed from the ſame center as the bottom of the chamber, and touching the lines drawn parallel to its ſides.

As all the neceſſary dimenſions are ſet down here accurately, the reader may eaſily conſtruct theſe mortars by the help of the plate, which ſhews their form; for which reaſon we ſhall inſiſt no farther upon them.

Dimenſions of ſea mortars in inches. Fig. 6, 7.

Diameter of the bore — —	13	10
Length of the mortar — —	63	56
From the muzzle to the reinforce	21	20
Length of the { reinforce ——	18	12
Length of the { bore — —	24	30
Length of the { chamber ——	21	15
Its greateſt diameter — —	8.5	6.6
Its leaſt diameter — —	7	6
Breadth of the muzzle ring —	3	2.4
Of the muzzle, ogee, and fillet	1.9	0
From the muzzle to the aſtragal	0	.4
Of the aſtragals — —	0	1.6
Of the { reinforce rings ——	1.9	0
Of the { ogees next to them —	4.5	2.2
Of the { chace ring — —	1.5	0
Of the { chace ogee — —	2.2	0
Of the { chamber aſtragal ——	0	1.6
Thickneſs of metal at the muzzle	4.7	2.8
At the muzzle ring — —	5.$\frac{3}{4}$	6
Near the reinforce — —	4.7	3.3
At the reinforce — —	8	6
Behind the reinforce — —	9.5	6
Trunions length from end to end	45.4	36

Its

Its greatest diameter — —	12	0
Its least diameter — —	10	8
Length of the part diminished —	6	0
Chamber contains powder ℔	32	12 : 8
Weight of the mortar — C.	81 : 1 : 18	32 : 3 : 7

N. B. The thickness of metal at the muzzle, and near the reinforce, is taken from the lines produced, which determine the bore of the mortar; and behind the reinforce it is taken from the lines, which terminate the chamber. The round part or the breech of the mortar is circular, and described from the same center as the bottom of the chamber in the 10 inch, and so as to come within 3.5 inches of the end of the mortar in the 13 inch; and in both so as to touch the outlines, which are drawn parallel to the sides of the chamber.

The reader may easily perceive, that wherever stands an 0 in the two last tables, there is no such dimension in that mortar; for there are mouldings in one which are not in the other.

Dimensions of HOWITZES *by inches.* Fig. 8.

Diameter of the bore — —	10	8
From the muzzle to the reinforce	19.4	16
Length of the reinforce ——	11.9	10.7
Total length of the howitz —	50.4	37.4
Length of the { bore — —	29.2	25.9
Length of the { chamber —	16.8	9.9
Its greatest diameter — —	6.5	4.6
Its least diameter — —	5.6	4
Breadth of the muzzle ring —	1.7	1.25
From the muzzle ring to the astragal	4.3	4.6
Breadth of the astragal ——	1.3	.7
Of the ogee before the reinforce	2.	1.4
Of the ogee behind the reinforce	1.7	0

 Of

Of the aſtragal — —	1.4	.7
Of the baſe ring — —	1.8	1.25
From the baſe ring to the aſtragal	2.2	0
Breadth of the aſtragal —	1.3	0
Thickneſs of metal at the muzzle	1.75	2.25
At the muzzle ring — —	5	3.4
Near the reinforce — —	3.4	2.6
At the reinforce — —	5.0	3.4
Behind the reinforce — —	4.4	2.5
Diameter of the baſe ring —	20	14.7
Diameter at the vent aſtragal —	17.5	12.5
Diameter of the caſcable —	8.25	7.6
Diameter of the button —	7	3
Diameter of the neck —	5	3.5
Breadth of the ogee and fillets	1	.9
Of the ſecond ogee and fillets	1.6	.9
Diameter of the firſt fillet —	11.13	9.5
Diameter of the ſecond —	7.64	4.5
Length and diameter of the trunion	6.	4.4
From the fore reinforce to the trunion	2.	1.2
Chamber contains powder ℔	18	4
Weight of the howitz — C.	31 : 2 : 26	12 : 1 : 11

Remarks on the conſtruction of MORTARS.

Of all the parts of Artillery, the conſtruction of mortars is the moſt variable and uncertain; almoſt every artilleriſt has ſome favourite notion or other concerning their figure. Mr. *Belidor* mentions, in his *Bombardier François*, four different chambers; namely, the cylindric, the ſpheric, the conic, and the bottled; of theſe he ſays the cylindric is the worſt, and the conic the beſt; for, ſays he, the vent being at the end of the cylindric chamber, prevents the powder from taking fire ſo quick as in the conical one; he alledges likewiſe another reaſon againſt the uſe of theſe chambers, which is, that they are ſeldom caſt ſo as their axis correſponds with

with that of the bore, whereby the direction of the ſhell becomes variable and uncertain.

But ſince there is no neceſſity for placing the vent at the end of the chamber, as he ſuppoſes, all his arguments, on that account can only be againſt the preſent practice, and by no means proves their badneſs; and had he conſidered the exploſion of powder as an elaſtic fluid, as he ought, he would have eaſily perceived that the direction of the chamber, with regard to that of the ſhells, is of no conſequence, ſince the action of fired powder is every where perpendicular to the ſurface it acts upon. Beſides, according to the experiments I made, which are mentioned in the preface, the force of powder, when fired at the end, is greater than when fired in the middle. I dare not however infer, that the ſame thing will happen in larger mortars, becauſe I have found by experience, that we ought to depend upon nothing but what has been found to anſwer in pieces of the ſame caliber; and therefore all the different ſizes of mortars ſhould be tried and examined, to determine where the vent is to be placed in the moſt advantageous manner.

We have proved in the fifth Theorem, and the examples that follow, that the action of fired powder diminiſhes in proportion as the ſurface preſſed enlarges; the ſame thing we have likewiſe found by experiments, and therefore the conic chambers are the very worſt of all.

The late General *Borgard* made his chambers likewiſe conical, terminating in a circular form at the bottom, as has been ſhewn in the foregoing tables of the dimenſions; and ſo as the ſides of the chamber produced meet the extremities of the diameter at the mouth; imagining, I ſuppoſe, that the powder acts in right lines parallel to the ſides of the chamber. Though he was one of the braveſt officers of his time, and ſerved about ſeventy years, yet his qualifications as an inventor were but very moderate.

As to the advantage of concave chambers of any kind, it consists in this, that their entrance may be made narrower than those of any other form, and that this is a real advantage, we have proved both by theory and practice: yet when the entrance is so small, as not to admit of a man's hand, they are not easily cleaned; and if any sparks of fire should remain, cannot be so well extinguished; for which reason I would make them of this form only in sea mortars, because they are loaded with large quantities of powder, and in the land ones cylindric: since these latter need be charged with but little powder.

As to the vulgar notion, that mortars with concave chambers, when fired, shake their beds with great violence, and make the direction of the shell very uncertain, it is grounded upon ignorance, and deserves no notice.

The length of mortars is no more ascertained than the rest of the dimensions: the *French* make the length of the bore a diameter and an half of the shell; on the contrary, we make that of our land mortars two of these diameters, and three in the ten inch sea mortar, which causes a great difference in the weights; for our thirteen inch land mortars weigh C. 25 : 0 : 0, whereas the *French* weigh only C. 13 : 0 : 0.

It is a query, whether this difference produces any material advantage in the ranges; if not, it would be unnecessary to make them so long as we do, since this increase makes them so much the heavier. For the same thing (*viz.* that those guns which carry farthest are not the best) is also true in mortars; since if they carry their shells about 12 or 1500 yards with a moderate charge, it is in my opinion sufficient in respect to land mortars; because when they carry farther, the hitting an object becomes so extremely uncertain, as to render that advantage useless; therefore all means should be tried to make them as light as conveniently can be.

The

The thickneſs of metal in the different parts of a mortar, is as undetermined as the reſt; for not any two ſorts are equally ſtrong; ſome are as much too weak as others the reverſe, and thoſe who have the direction of theſe things are ſo ſlightly acquainted with the common principles of geometry, that when a mortar of any ſize is made with proper dimenſions, and has been found in practice to anſwer perfectly well, they cannot make another either leſs or larger, that ſhall ſtill retain the properties of the former.

The reaſon is, that commonly none but workmen are employed on them, whoſe knowledge conſiſts only in imitation and gueſs. For though a workman may be very capable to execute the work, or to ſee it done, yet it can hardly be ſuppoſed that he is able to determine the proper dimenſions of the ſeveral parts.

The parts of mortars are formed in imitation of thoſe of guns; for which reaſon they make them with a reinforce. This only overloads the mortar with a heap of uſeleſs metal, and that in a place where the leaſt ſtrength is required; yet, as if this unneceſſary metal was not ſufficient, they add a great projection at the mouth, which ſerves to no other purpoſe than to make the mortar top-heavy. The mouldings are likewiſe jumbled together, without any taſte or method, though they are taken from architecture.

As there has not the leaſt hint hitherto been given, with regard to a general rule to conſtruct all ſizes of mortars by, without which, the artilleriſt cannot poſſibly underſtand what he is about, nor can he judge whether he is right or wrong, whenever he attempts to conſtruct others of a different ſize from thoſe in uſe at preſent, he muſt remain in ignorance, let him take ever ſo much pains, we ſhall give the following rules.

General

General dimensions for land mortars.

Plate III. Fig. 9.

Diameter of the { bore —	30	30	30
Diameter of the { chamber —	10	10	10
Length of the { bore — —	54	45	40
Length of the { chamber —	22	21	20
From the end of the chamber to the end of the mortar — —	16	15	14
Total length of the mortar —	92	81	74
From the mouth *a* to the reinforce *b*	30	26	22
Length of the reinforce *b c* —	18	14	14
Breadth of the { muzzle ring and fillets	3. 5	3	3
Breadth of the { ogee next to it —	3	2	2
From the ogee to the muzzle astragal	5	4	3
Breadth of the { astragal and fillets	2. 5	2	2
Breadth of the { ogee before the reinforce —	3	2	2
Breadth of the { two ogees and fillets behind the reinforce —	6	5	4
Thickness of metal { at the muzzle	5	4. 5	4
Thickness of metal { near the reinforce	6	5	4. 5
Thickness of metal at the { reinforce	7	5. 5	5
Thickness of metal at the { chamber	12	12	12
Thickness of metal at the { muzzle ring	6.5	5. 5	5
Diameter of the trunions —	14	13	12
Length of the trunions from the mortar	15	14	13
Chamber contains powder —	d / 421	d / 442	d / 466
Weight of the mortar —	5d / 6	2d / 3	3d / 5

N. B.

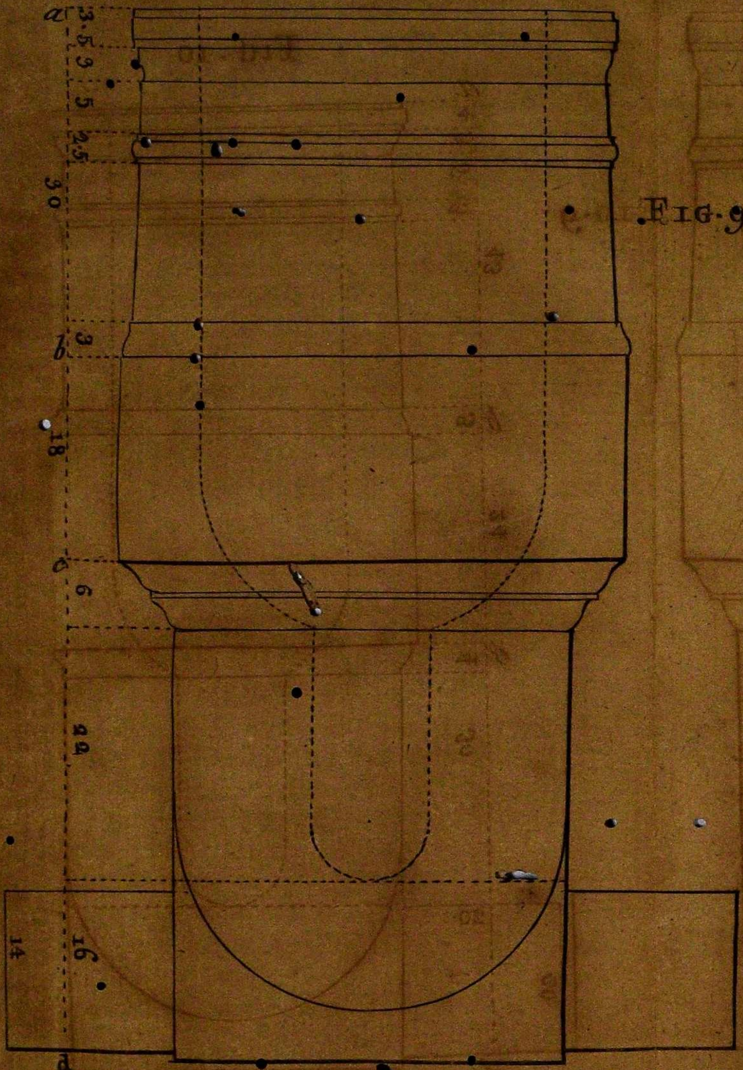
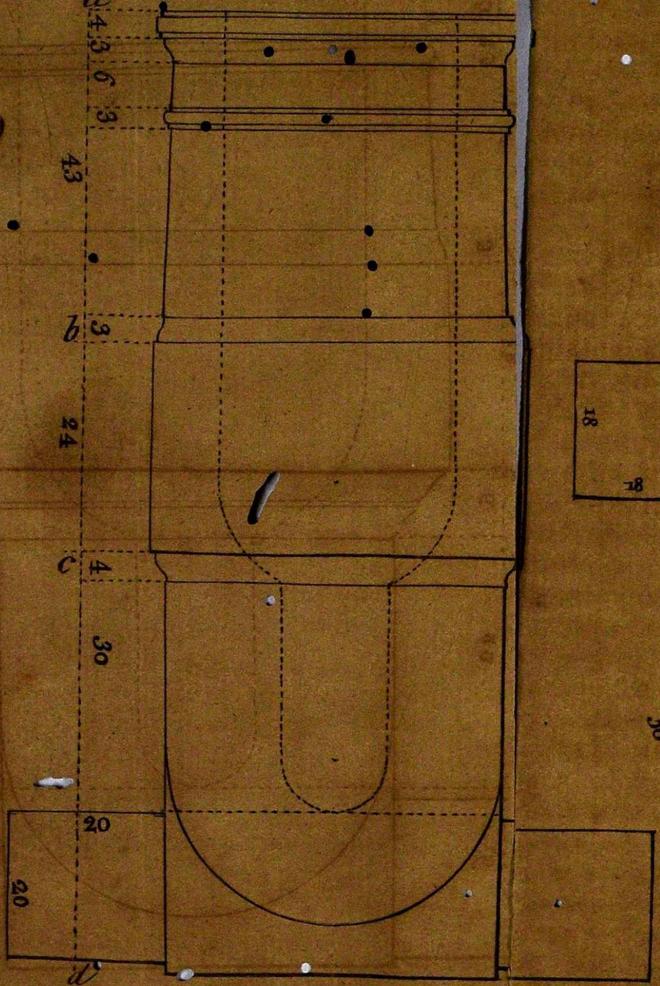


Fig. 9

Land Mortar

Fig. 10



Sea Mortar

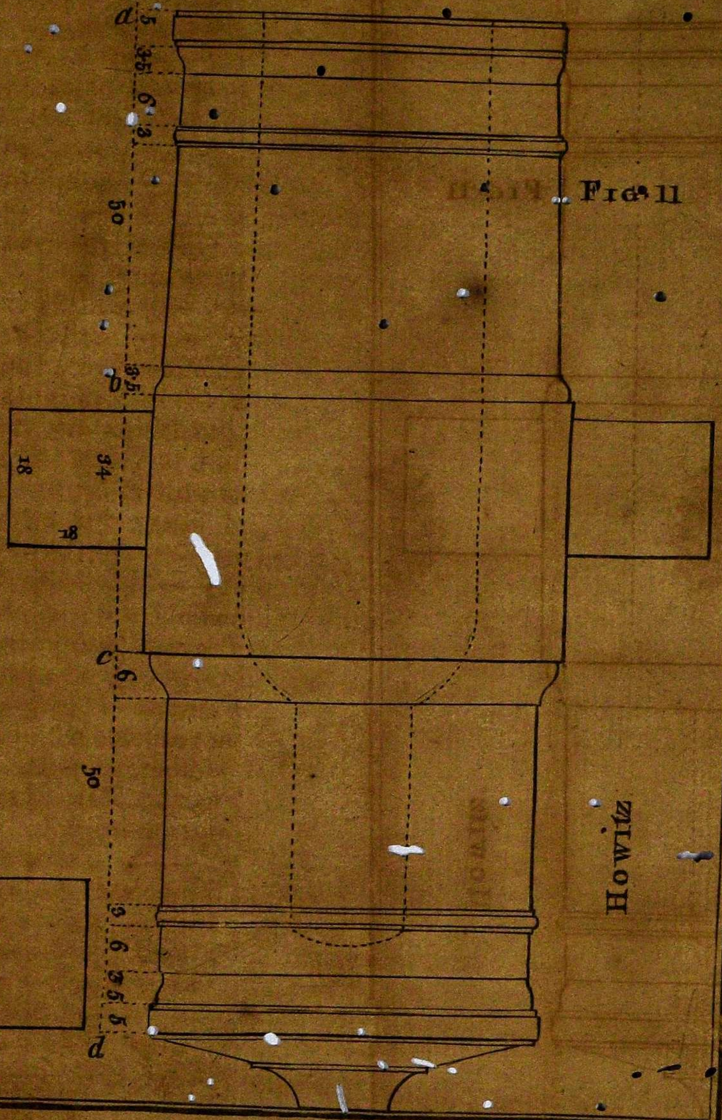


Fig. 11

Howitz

N. B. The chamber is cylindric, and the bottom a femi-fphere; the round part of the mortar is defcribed from the fame center as the bottom of the chamber. The letter d in the content of the chamber and that of the weight of metal, expreffes the cube of the diameter of the bore in inches; that is, $d = 2197$ in a thirteen inch mortar, and $d = 1000$ in a ten inch.

The reader may fee that the diameter of the bore is to be divided into 30 equal parts, for a fcale to fet off all the reft of the dimenfions. The fame fcale ferves to conftruct their beds, which renders the whole eafy and uniform, a neceffary confequence of well fettled principles.

Remarks on thefe dimenfions.

We have endeavoured to difpofe the metal in fuch a manner, as to make the ftrength of the parts nearly in proportion to the forces which act upon them: at the chamber it is fufficient, though lefs than in moft mortars now in ufe; for the thicknefs of metal there is greater than its diameter, which is more than ever has been allowed in any brafs gun whatever; it is true that the effort alfo is greater, but then an allowance has been made accordingly: we made a reinforce, merely to comply in fome manner with the common practice, though the mortar fhould be conical from the chamber to the mouth, according to the action of powder, as proved before; however, the difference between the reinforce and chace is no more than juft fufficient to admit of an ogee, whereby the mortar looks more graceful to the eye; at the mouth the projection is no greater than is neceffary for the mouldings, more would be fuperfluous, and make the mortar top heavy; befides, as we fuppofe it capable of being either raifed or depreffed, and not fixed to its bed, as hitherto the cuftom, that operation would thereby become more difficult. As to

to the vent, we do not pretend to determine its true place, though we have always found the nearer it was to the bottom the farther the ſhell went; but as theſe experiments were made with a three inch mortar only, no juſt concluſion can be drawn from thence with regard to larger.

The cylindric figure of the chamber, is, in my opinion, the beſt for theſe kind of mortars; for though we have ſhewn that the concave figure, or thoſe whoſe entrance was the leaſt, will throw the ſhell fartheſt of any with the ſame charge; yet in this caſe, where but little powder is required, their entrance would become too narrow and inconvenient to clean; whereas when they are cylindric, the difference between the advantage of the one and the other will be but little, and not attended with any inconveniencies.

Colonel *Deſaguliers* and myſelf made ſeveral experiments with different chambers, which contained the ſame quantity of powder, and we found that the cylindric threw the ſhell always farther than any other whoſe entrance was larger, and more eſpecially when they were not quite filled. We made likewiſe ſome other experiments, which were, by putting as much powder as would fill half the chamber into a cartridge made of common writing paper, and when it was put into the chamber, ſo as to be cloſe to the ſhell, leaving a vacancy at the bottom, it threw the ſhell near twice as far as when the cartridge touched the bottom, and the vacancy was left between the ſhell and the powder; we repeated this experiment ſeveral times,and found always the ſame effect. Another remarkable thing happened; I put a piece of common writing paper upon the powder, the chamber being but partly filled, and the ſhell went much farther than with the ſame charge when there was no paper. Laſtly, we compared two chambers of the ſame content, the one cylindrical, and the other conical; they had both the ſame height, and the diameter of the bottom of the conical one was but half the diameter of the

the entrance, and when these chambers were not quite full, the cylindric one threw the shell much farther than the other, and this happened as often as the experiment was repeated. Whoever considers these experiments with some attention will find, that we know very little of the effects of gunpowder as yet, and that we ought to depend upon nothing but what has been tried.

That our chambers hold a sufficient quantity of powder for any occasion whatever, has been proved by experiments; for I fired a three inch mortar, with an ounce and a quarter of powder, at an angle of elevation of 45 degrees, and the shell went 1200 yards; and since our mortars are similar to that tried, the powder will give the shell the same velocity; but because the resistance of the air is in this case inversely as the shells diameters, the three inch shell will meet above four times the resistance of a thirteen inch shell; from whence, and some other experiments made upon *Woolwich Common*, with the present thirteen inch mortar, I conclude, that the shells in our mortar will range about a mile, which is more than is wanted; for when the ranges are greater, they are so uncertain, and it is so difficult to judge how far the shell falls short, or exceeds the distance of the object, that it serves to no other purpose than to throw away the powder and shell, without being able to do any execution.

The first of these mortars is of the same length with our land mortars; the second with the *French*; but the third is shorter than either. The reader may easily see, that these dimensions are general for any size of mortars whatever, as all constructions ought to be, whereby they become all alike; and consequently one of them being found strong enough by practice or experience, all the rest will be so too; which can never be the case in particular constructions, as hitherto has been the case in all countries so far as I know.

To

To find the weight of metal.

The ſquare of the mean diameter 41 of the muzzle part, multiplied by 30, gives —	50430
The ſquare of the diameter 44 of the reinforce, multiplied by 18, gives — —	34848
The ſquare of 34, the chamber part, multiplied by $34\frac{1}{3}$, gives — —	39689
Four times the trunion 2940, for the trunions and mouldings — — —	11760
Sum total in cubic parts of the diameter of the bore — — —	136727
The content of the bore in like parts is —	44100
The content of the chamber is —	2033
The two laſt ſums ſubtracted from the content of the mortar, leaves — —	90594
This reduced in the ratio of 452, to 355, of the ſquare of the diameter to the circle, gives — — —	71152
Then as 192 cubic inches weigh 61 pounds of metal, we get — —	22605

But as the diameter *d* is divided into 30 equal parts; if we ſay, as the cube of 30 is to the cube *d*, ſo is 22605 to the weight of the mortar of the firſt ſort, it will be found to be $\frac{5}{6}d$ nearly. In the ſame manner are found the weights of metal of the other two mortars.

To find the contents of the chambers.

The ſquare of 10 multiplied by the length, reduced $20\frac{1}{3}$, gives 2033 in the firſt mortar; but as the diameter is divided into 30 equal parts, if we ſay as the cube of 30 is to the cube *d*, ſo is 2033 to $\frac{2033}{27000}d$, we get

get the cubic parts of the diameter. Now, becaufe the diameter of a cylinder, which holds one pound of powder, is 3.165, according to Sir *Jonas Moor*, if we divide the laft number by 31.7, the cube of that diameter, we fhall have $\frac{2033}{855900} d$, for the content of the chamber; which being reduced, gives $\frac{d}{421}$ or $\frac{d}{531}$ nearly. In the fame manner are found the contents of the chambers of the other mortars.

In order to compare thefe mortars with thofe ufed at prefent, we fhall infert their weights and charges in the following tables.

Weight of the new mortars.

Diam.	13	10	8	6
Firft	16 : 1 : 10	7 : 1 : 21	3 : 3 : 6	1 : 2 : 11
Second	13 : 0 : 0	5 : 3 : 22	3 : 0 : 0	1 : 1 : 0
Third	11 : 3 : 0	5 : 1 : 12	2 : 2 : 27	1 : 0 : 15

Weight of the powder.

Diam.	13	10	8	6
Firft	5 : 3	2 : 6	1 : 3	0 : 8. 2
Second	4 : 15	2 : 4	1 : 2	0 : 7. 8
Third	4 : 11	2 : 2	1 : 1	0 : 7. 4

Weight

Weight of the preſent mortars.

Diam.	13	10	8	5.8	4.6
Wt.	25 : 0 : 0	10 : 2 : 18	4 : 0 : 10	1 : 1 : 0	0 : 3 : 0
Cham.	9 : 1 : 8	4 : 0 : 0	2 : 0 : 10	1 : 0 : 0	0 : 8 : 0

Hence if we compare the weights of our mortars with thoſe of the preſent ones, we ſhall find the difference between the 13 inch to be, 8 : 2 : 18; between the 10 inch, 3 : 0 : 15, and between the 8 inch, 0 : 1 : 4. Now as the difference between the weights of the 13 inch mortars, is much greater than between any others, it is evident they are much heavier in proportion than they ought to be, in reſpect of the ſmall ones; it appears therefore, that no true proportion has been obſerved in their conſtruction.

Though our mortars are ſo much lighter than the preſent ones, yet I may affirm, they are equally ſtrong, becauſe they are as thick at the chamber as they need be; and at the muzzle, or where the leaſt thickneſs is, ours are ſtronger; for the 8 inch mortar is but an inch in that place, whereas ours is 1 inch and a third; the 10 inch, is 1.6 inches thick, ours $1\frac{2}{3}$; and as to the reinforce, it is loaded with more metal than it need be, ſince the force of powder is very little more there than at the muzzle. But the difference between the weights ariſes chiefly from the chambers, which are both wider and longer in the preſent mortars than in ours, and therefore they require more metal.

General Dimenſions of howitzes. Fig. 11.

Diameter of the bore, — —	30	30	30
Length of the bore, — —	90	90	97.5
Diameter of the chamber, —	15	15	15

Length

Length of the chamber, — —	33	33	33
From the muzzle a, to the reinforce b, — —	50	50	54.5
Length of the reinforce b c, —	34	34	37
From the reinforce c, to the end of the howitz, — —	50	50	50
Total length of the howitz, —	134	134	141.5
Thickneſs of the metal at the muzzle, — —	8	7	8
Thickneſs near the reinforce —	9	8	9
Thickneſs at the reinforce, —	10	9	10
Thickneſs at the chamber, —	16	15	16
Breadth of the muzzle and baſe ring, fillets included, —	5	5	5
Breadth of the ogees, that behind the reinforce excepted, —	3.5	3.5	3.5
Diſtance between the muzzle and breech, ogees and aſtragals, —	6	6	7
Breadth of the aſtragals and fillets,	3	3	3
Breadth of the ogee behind the reinforce, — —	6	6	6
The muzzle and baſe ring project the metal by — —	1.5	1.5	1.5
Length of the trunions —	18	18	18
Diameter of the trunions —	15	15	15
Diſtance of the trunions from the fore end of the reinforce, —	5	5	5
	d	*d*	*d*
The chamber contains powder, —	116	116	116
Weight of the howitz, —	2.25*d*	1.97*d*	2.4*d*

The caſcable is 24 parts long, the radius of the button 8, the ogee and fillet included 4.

The reader may obſerve, that for want of room in the plate, the button could not be marked, which he may eaſily ſupply from the given dimenſion in the ſame manner as in guns.

The dimensions of the first howitz are nearly the same as those of the present, the chamber part excepted; the reinforce is not so strong as it is commonly made, without any ground or reason, because the force of explosion acts but very little more there than at the muzzle. The dimensions of the second are less, and yet I am persuaded sufficient; for a 6 inch howitz is an inch and .4 thick near the muzzle, whereas the present 8 inch mortar is barely an inch in that place; for which reason I would prefer the second sort before the first, because there can be no reason assigned to load them with more metal than is necessary.

The third sort is a quarter of the bore's diameter longer than the other two, and the rest of the dimensions the same as the first; hence the artillerist is left to his choice to use which he likes best.

Weight of the howitzes and powder.

Bore, —		13	10	8	6
Weight	1st,	44 : 0 : 13	20 : 0 : 9	10 : 1 : 0	4 : 1 : 5
	2d,	38 : 2 : 8	17 : 2 : 3	9 : 0 : 0	3 : 2 : 24
	3d,	47 : 0 : 7	21 : 1 : 14	10 : 3 : 13	4 : 2 : 6
Powder,		18 : 15 : 0	8 : 9 : 14	4 : 6 : 9	1 : 13 : 12

Weight of the present howitzes and powder.

Bore, —	10	8	5.8
Weight	31 : 3 : 26	12 : 1 : 6	4 : 0 : 18
Powder,	18 : 0 : 0	4 : 0 : 0	1 : 0 : 0

From

From theſe tables of the weights of howitzes, we ſee that the preſent 10 inch weighs about one third more than it ſhould do in reſpect to the 8 inch, for the weights ſhould be in proportion to the cubes of the diameters. Now the cube 512, of 8, is to the cube 1000, of 10, as the weight 12 : 1 : 6, of the 8 inch, is to the weight 24 : 0 : 3, which ſhould be the weight of the 10 inch. Whence it evidently appears, that no better proportions have been followed in conſtructing howitzes than mortars.

This ſuperfluous weight of the 10 inch howitz has occaſioned its diſuſe, at leaſt theſe 25 years; whereas by obſerving a due proportion, and ſuch as our ſecond ſort, not only a 10 inch but even a 13 inch might have been uſed, if it had been thought proper. It may be obſerved again, that though ours are ſo much lighter than the others, they are full as ſtrong, becauſe the metal is better diſpoſed over all the parts, and there is not that uſeleſs lump at the muzzle, reinforce, and trunnions, as in thoſe made at preſent.

It is to be wondered that no greater uſe has hitherto been made of howitzes, ſince the ſhells may do execution likewiſe as ſhots, and beſides grapes of ſhots, or ſhells, might be fired out of them to more advantage than out of guns, eſpecially in a ſiege where the diſtance is but ſmall; and in the field, if they were placed in the flanks, or between the battalions; the terror they would cauſe, eſpecially amongſt the horſe, by rolling amongſt the ranks with the fuſe burning, and the expectation of their burſting every moment, would diſorder the braveſt men, by means whereof they might eaſily be broke, and the day thereby won.

In a ſiege where the works are not lined with walls, or when the walls are once battered down by cannon, there can be no ſpeedier way to complete the breach than by firing ſhells into them; for they will lodge in the earth, and when they burſt will produce the ſame effect as mines. This practice has been recommended by

 St. Remy,

St. Remy, and the *French* followed it in the siege of *Bergen op-zoom*, where they chiefly used mortars, mounted upon field carriages for that purpose; besides, when you are pretty near the enemy's works, grapes made of shells will do wonderful execution, as I have been assured by some artillery officers, who have tried it, and found that all the fuses took fire.

As howitzes are easier carried from one place to another than mortars, which require also a good deal of time to prepare the ground, to lay the beds, and mount them, the use of the former would be more convenient than the latter in all cases, except in throwing shells upon powder magazines. It may be observed, that the wheels and axletree of the present 10 and 8 inch howitz carriages, are of the same strength as those of a 24 and 18 pounder's carriages, without any judgment or reason. For since the wheels of an 18 pounder's carriage support a weight of 48 : 0 : 0, which is just four times the weight of the 8 inch howitz, there is not the least proportion observed between the weight and the strength to support it; it is true, that an 8 inch shell is heavier than an 18 pound ball, but when it is considered that the force of the shell affects the carriage in its recoil only, and not at all the wheels; this can be no reason for making them so strong as has hitherto been the custom.

Of Sea Mortars.

As these mortars are generally fired at a much greater distance than ever is required by land, they are made something longer and much heavier than the land. Their proper dimensions can only be determined from their charges of powder. The chamber of the present 13 inch holds 32 pounds of powder, though the late General *Borgard* told me, he never made use of more than 12 pounds, and as he had more experience in that service than perhaps any other, we may depend on what

he

he ſaid; beſides, ſome very expert officers employed in the late war aſſured me they never exceeded the charge of 15 pounds. Now, as this chamber is never half filled, the powder won't act ſo forcibly as if there was no vacant ſpace between the charge and the ſhell; it is therefore plain, that a charge of 12 or 15 pounds of powder at moſt will be ſufficient; beſides this chamber being conical, and its greateſt baſe two thirds of the diameter of the bore, leſſens the force of powder conſiderably, and more ſo when not filled, as Colonel *Deſaguliers* and myſelf found by ſeveral experiments made with ſuch a chamber, and compared with a cylindric one of the ſame content. This being an undoubted fact, the following dimenſions will, I may venture to affirm, be ſufficient in all reſpects.

General dimenſions of ſea mortars. Fig. 10.

Diameter of the bore divided into — —	30	30
Length of the bore, — — —	75	75
Diameter of the chamber, — —	15	15
Length of the chamber, — —	33	33
From the end of the chamber to the end of the mortar, — — —	20	20
Total length of the mortar, — —	128	128
From the muzzle a, to the reinforce b, —	43	43
Length of the reinforce b c, — —	28	28
Thickneſs of the metal at the muzzle, mouldings excepted, — — —	8	7
Thickneſs of metal { near the reinforce, —	9	8
Thickneſs of metal { at the reinforce, —	10	9
Thickneſs of metal { at the chamber, —	16	16
Breadth of the { muzzle ring and fillets, —	4	4
Breadth of the { ogee next to it, and of that before the reinforce, —	3	3
Diſtance from the ogee to the muzzle aſtragal, — — —	6	6

Breadth of the { aſtragal and fillets, —	3	3
Breadth of the { ogee behind the reinforce,	4	4
The muzzle ring projects the metal, by —	1.5	1.5
Diameter of the trunions, — —	18	18
Length of the trunions from the mortar, —	20	20
	d	d
The content of the chamber, — —	126	126
Weight of the metal, — —	2.1d	1.8d

The arcs which determine the round part of the mortar are deſcribed from the ſame center which determines the bottom of the chamber: the weight of metal, and that of the powder which the chamber contains, have been found in the ſame manner as in the guns, allowing four times the value of one trunion for the trunions and mouldings.

Weight of ſea mortars and powder.

Diameter of the bore,	13	10
Weight of { preſent ſea mortars,	81 : 1 : 18	32 : 3 : 7
Weight of { the firſt new mortar,	41 : 0 : 19	18 : 2 : 19
Weight of { the ſecond, —	35 : 1 : 2	16 : 0 : 7
Powd. cont. in { preſent mortars,	32 : 0 : 0	12 : 8 : 0
Powd. cont. in { new mortars, —	17 : 7 : 0	8 : 0 : 0

The enormous weight of the preſent 13 inch mortar proceeds from the antient notion, that thoſe pieces which throw a ſhell fartheſt are the beſt; for which reaſon the artiſt imagined, that the heavier they were, the farther they would carry. But by the account of all thoſe artillery officers whom I have converſed with, and who have been employed in that ſervice, the ſhip or bomb-ketch is not able to bear the ſhock of thoſe mortars, when loaded with their chambers full of powder; and conſequently it is ridiculous to make them ſo heavy.

The

The firſt of the new mortars is as ſtrong at the muzzle as the 10 inch preſent one, and conſequently ſtrong enough upon all occaſions; and I may venture to affirm, that the ſecond ſort is ſo too; ſince it is above twice as ſtrong as the land. With regard to the ſize of our chambers, we have ſhewn before, that they never uſe above 15 pounds of powder in bombarding; we have likewiſe proved in the theory of powder, as well as by ſeveral experiments, the great advantage a cylindric chamber has over the conic when the greateſt baſe is uppermoſt, ſo that there cannot remain the leaſt doubt but that our chambers are full as large as they need be on any occaſion.

It may appear ſtrange to ſome of my readers, that mortars ſo much lighter than the preſent ſhould be near equally ſtrong. I account for it in this manner, their chambers are near twice as long as ours, and as the thickneſs is very great in that place, there muſt needs be a great deal more metal there than is neceſſary; the ſame thing may be ſaid with reſpect to the reinforce part, which without any reaſon is made about twice as ſtrong as the muzzle part; though the force of exploſion is nearly the ſame in both places. This was never conſidered in the conſtructions of old mortars.

In the bombarding of *Havre de Grace*, the mortars were fired quick and with a full charge, by which they were ſpoiled and rendered uſeleſs in a ſhort time; for the vents grew ſo large, and the metal melted in the chambers, that it would have been dangerous to fire them any more, and ſo were rendered entirely uſeleſs.

It has been obſerved both in guns and mortars, that the great thickneſs of metal, inſtead of being an advantage, renders them ſooner uſeleſs. For at the battle at *Lafeldt* ſeveral 6 pounders, that weighed 1900, were ſpoiled, and the light, which weighed but 4 : 3 : 0, received no damage; and our ſea mortars generally fail when much fired with great charges; whereas the land, which do not weigh one third of the others,

IV Sea Mortar

With a Concave Chamber.

Stone Mortar

Fig. 12

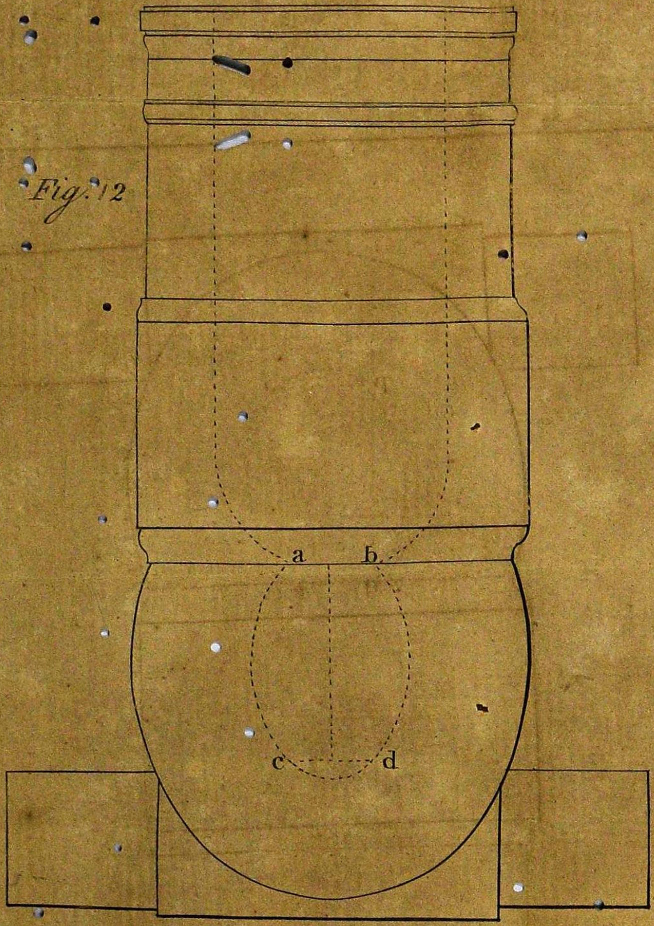
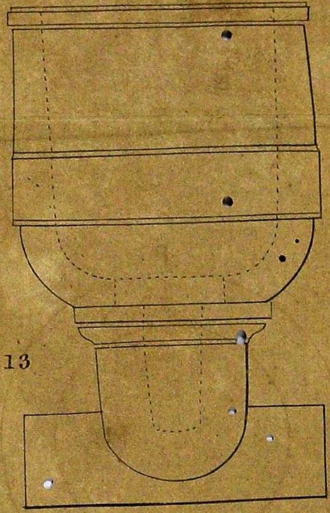
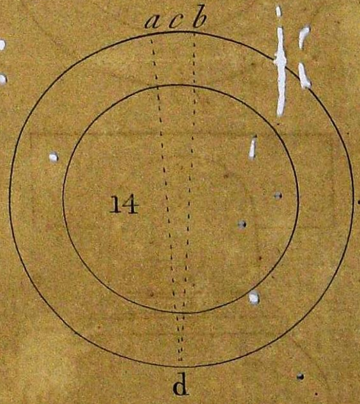


Fig 13





chamber; becauſe the few experiments I made ſhewed that to be the beſt place in ſmall mortars.

SHELLS. Plate IV. Fig. 14.

As the dimenſions of ſhells are undetermined, and no proportion obſerved therein, nor is it known how much the thickneſs of the bottom ought to exceed that at the fuſe hole, ſo as they may burſt in the greateſt number of pieces, we have in the following dimenſions obſerved the proportions of the preſent 13 inch ones; ſo that if they are right, we are certain that ours will be ſo too; but if it ſhould ſo happen, that the ſhell of any other caliber is found to have a better proportion than that we have made uſe of, the general dimenſions may eaſily be made in the ſame proportion, by ſaying, the diameter of the ſhell is to 30, as any part expreſſed in inches, is to the ſame part, expreſſed in parts of the diameter divided into 30 equal parts.

Diameter	of the bore,	30
	c d of the ſhell,	29. 5
	of the hollow ſphere,	21
Thickneſs	of metal at the fuſe hole,	3. 5
	at the bottom or oppoſite part	5
Diameter a b of the fuſe hole,		4

	d
The weight of the ſhell unloaded,	11. 7
Weight of the powder the ſhell contains	236. 5

The fuſe hole is conical, and when produced, terminates at the extremity d of the diameter c d, which paſſes through the center.

There are two handles of hammered iron fixed in the mould when they are caſt, which faſten to the ſhell, and ſerve to lay hold on when the mortar is to be loaded thereby, as likewiſe to carry them from one place to another.

other. In *France* theſe handles are caſt iron; but this renders them clumſier, and liable to break ſooner than the others. The letter *d* ſtands here for the cube of the diameter of the bore, as well as in the conſtruction of mortars.

Two reaſons are given for making ſhells thicker at the bottom than at the fuſe hole; one is, that they are thereby better enabled to reſiſt the ſhock or impreſſion of the powder that diſcharges them; the ſecond, that the ſhell always falling with the heavieſt part undermoſt, the fuſe will of courſe be uppermoſt, and therefore will not be extinguiſhed by its fall. Both theſe reaſons are, in my opinion, of no conſequence; for if the ſhells were every-where equally thick, and of the ſame weight as thoſe above-mentioned, the blaſt of powder lodged in the chamber would hardly be able to break them; and as to the fuſe falling uppermoſt or not, that is of no detriment, ſince the compoſition of fuſes is ſuch, that nothing but an abſolute ſtoppage from the air is able to choak them; for they burn in water as well as any other element; for which reaſon I would make them every-where equally thick, becauſe they would then burſt into a greater number of pieces. But to be certain, it would be eaſy to make the experiment.

The quantity of powder they ought to be filled with, ſo as to burſt into moſt pieces, is not known; but moſt artilleriſts agree that they ſhould not be quite full; and Colonel *Deſaguliers*, after having made ſeveral experiments, imagines, that two thirds of the weight which would fill them is the quantity they ſhould be loaded with.

Weights of the preſent ſhells and powder.

Bore,	13	10	8	5.8	4.6
Wt.	1 : 2 : 15	0 : 2 : 25	0 : 1 : 15	0 : 0 : 12	0 : 0 : 7
Powd.	9 : 4 : 8	4 : 14 : 12	2 : 3 : 8	1 : 1 : 8	0 : 8 : 0

Weights

Weights of the new shells and powder.

Bore,	13	10	8	5.8	4.6
Wt.	1 : 2 : 15	0 : 2 : 27	0 : 1 : 14	0 : 0 : 16	0 : 0 : 8
Powd.	9 : 4 : 8	4 : 3 : 10	2 : 2 : 10	0 : 13 : 3	0 : 6 : 9

It is to be observed, that the windage of the present shells is a quarter of an inch, let them be great or small, which is contrary to all reason; whereas we allow $\frac{1}{60}$ part of the bore's diameter, which is something less in a 13 inch one, and decreases in proportion to the shell's diameter; whereby our small shells become something heavier than the present.

There is another kind of mortar which serves to fling stones into an enemy's works, when near at hand; such as from the town into the trenches in the covert way, or upon the glacis, and from these trenches into the town, or ravelins. As we have none of that sort here, I shall give such dimensions as agree nearly with those mentioned in *St. Remy*, whose diameter is 15 inches.

Dimensions of stone mortars. Fig. 13.

Diameter of the bore, — —	30
Length of the { bore, — —	37
Length of the { chamber, — —	16
Its greatest diameter, — —	8
Its least diameter, — —	6
Diameter of the cylindric part to hold a wooden tapeon, — —	14
Depth or axis of that cylinder, — —	3
From the muzzle to the reinforce, — —	20.5
Length of the reinforce, — —	8

Thickness

Thickneſs of the metal at the	muzzle. —	3. 5
	reinforce, —	4. 5
	chamber belt,	9
	entrance of the chamber, —	6
The chamber enters into the trunions, by —		2
Diameter of the trunions, — —		40
Length from end to end of the trunions, —		40
Breadth of the	muzzle ring and fillets, —	3
	chamber belt, — — —	2
	ogee next to this belt, —	3
		d
Content of the chamber, —		1102
Weight of the metal contained in this mortar,		3. 1

The bore is terminated by two quadrants of a circle, terminated by the reinforce and lines drawn from the ends of the cylinder made to lodge the tapeon parallel to the axis of the mortar; and the round part on the outſide are arcs deſcribed from centers, taken in the line which terminates the reinforce, and ſo as to meet the extremities of the belt. The bottom of the conic chamber is terminated by an arc of 60 degrees, and the round part of the outſide is a ſemi-circle.

Thus a 15 inch ſtone mortar weighs 10 : 3 : 4, and the chamber contains 3 pounds of powder; this agrees very nearly with the *French* mortar of the ſame ſize, which weigh 1000 pounds. When it is conſidered that we made the chamber part ſtronger than theirs, we conceive that this mortar may likewiſe ſerve to throw baſkets full of hand-grenades, which will be much more dangerous to an enemy than ſtones.

The reader may eaſily perceive, that the conic chamber is very proper here in this caſe, as a great force is not ſo much required as the extent of that force againſt the tapeon, for fear it might break it in the middle. The

The form of the bore at the bottom being different from that in other mortars, is likewise adapted here to the bodies to be thrown out of it; baskets are made to fit the bottom of the bore, which, when filed, are let into the mortar by means of two handles, in order to load it quicker. The stones generally made use of upon this occasion are pebbles the bigness of a man's fist, and as round as can be found. But as we said before, hand-grenades or small shells made for that purpose, of about two or two and a half inches diameter, will answer the purpose much better than stones. This has been practised at *Bergen-op-zoom* with a common mortar, and succeeded to the satisfaction of the artillery officers who tried the experiment.

Having thus given general constructions for mortars used on all different occasions either by sea or land, it remains to shew in what the use of howitzes differs from that of common mortars; as they are carried upon gun travelling carriages, they are easily transported in the field from one place to another, and are more readily fired than the others; they have likewise another advantage, which is, that they may be laid to any elevation, whereas the common mortars are fixed upon their beds at an angle of 45 degrees, whereby they are not so useful in a siege: for the shells thrown into the works, either from the trenches into the fortification, or from the fortification into the trenches, should always be directed in a less elevation than 45; and when they are to be thrown upon powder magazines, or any other building, with an intention to destroy it, the elevation should be greater, in order that they may fall with more force.

All these considerations are seeming advantages in favour of the howitzes; but if we consider that a 10 inch howitz weighs considerably more than a 13 inch mortar, and an 8 inch one more than a 10 inch mortar, it is easily perceived that the use of howitzes is not so superior to that of common mortars as is imagined by most artillerists. As to the different degrees of elevations in

which

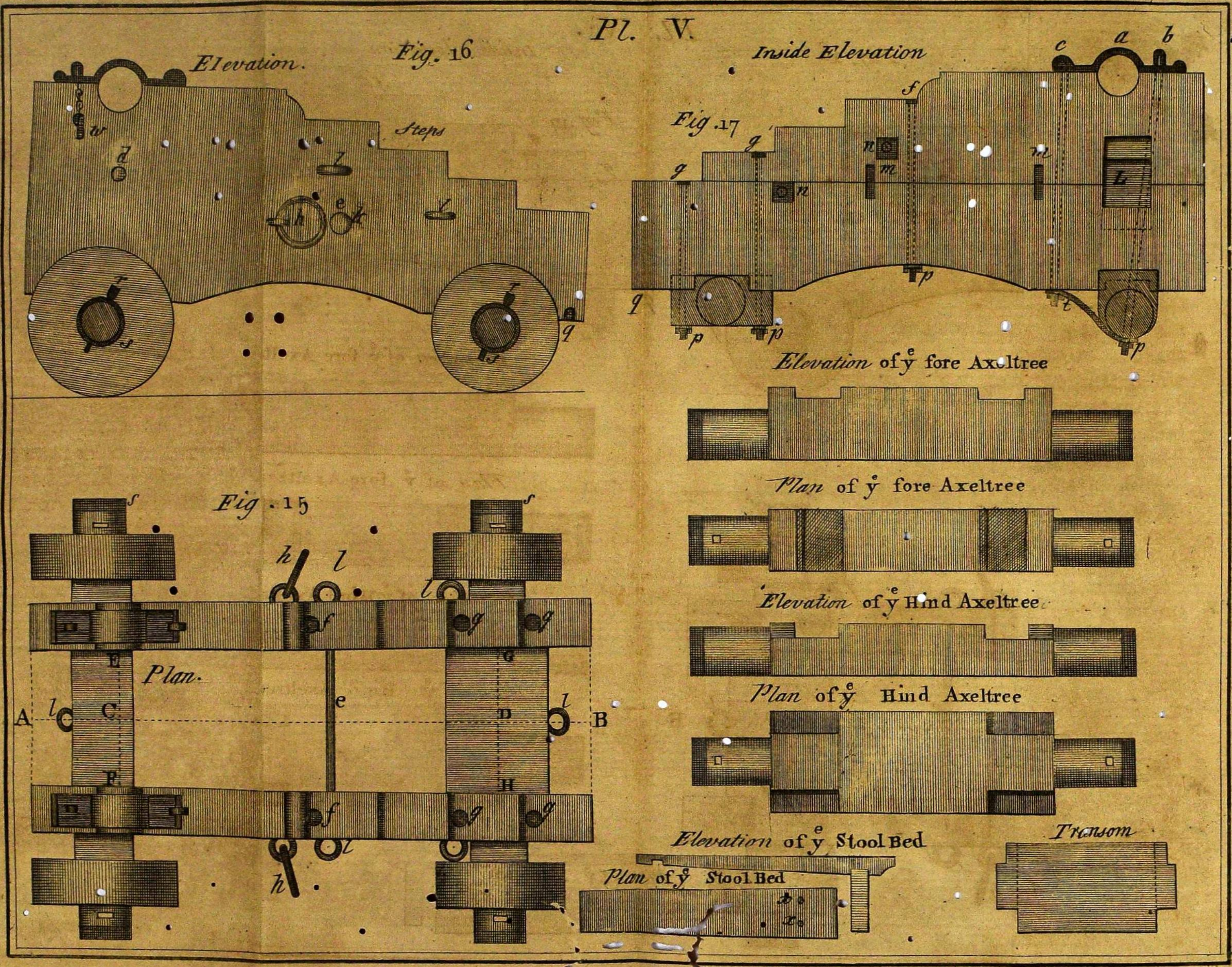
which they may be directed, it is a property that mortars ought to have as well as they. For there is not the leaſt occaſion to fix them on their beds ſo as not to be moved, ſince no nation but this does it; nor to laſh them on their beds with ſo much cordage, as if their weight was not ſufficient to keep them in their ſituation. The reaſon given for this practice is, that if they were not laſhed to their beds they would kick up before, and fall backwards, which is trifling, and inconſiſtent with the rules of mechanics; beſides the *French* mortars, which are much lighter than ours, and are not tied, never overſet; and as no nation makes more uſe of them than they do, it is very improbable they ſhould neglect a thing of that kind if there was any neceſſity for it.

As to the advantage of carrying howitzes upon travelling carriages, it is as inſignificant as the reſt, ſince no reaſon can be given why mortars may not be carried in the ſame manner. That this may be done, appears from the practice of the *French* during the laſt war. But what will not people do to ſupport an old cuſtom let it be ever ſo abſurd?

PART IV.

Conſtruction of ſhip and travelling Carriages.

THERE are three different ſorts of gun carriages; namely, thoſe uſed in garriſons, at ſea aboard ſhips, and in the field. The two firſt differ only in ſome iron rings, and alſo that the trucks or wheels of garriſon carriages are made of caſt iron; whereas ſhip carriages are of wood; but the reſt of the conſtruction is the ſame.


Pl. V.
Elevation.
Fig. 16
Steps
Inside Elevation
Fig. 17
Elevation of ye fore Axeltree
Fig. 15
Plan.
Plan of ye fore Axeltree
Elevation of ye Hind Axeltree
Plan of ye Hind Axeltree
Elevation of ye Stool Bed
Plan of ye Stool Bed
Transom
A
B
C
D
E
F
G
H
L

Conſtruction of ſhip and garriſon Carriages.

Plate V. Fig. 15.

In a line A B, take two points C, D, ſo as their interval be equal to the diſtance from the center of the trunions to the extremity of the breech, that is, equal to three ſevenths of the gun's length; through theſe points draw two lines at right angles to AB; in the firſt take CE, CF, each equal to half the diameter of the ſecond reinforce ring; and in the ſecond DG, DH, each equal to half the diameter of the baſe ring; then the lines drawn through the points E, G, and F, H, will determine the width within of the carriage.

If to theſe lines there be drawn two parallels at a caliber's diſtance, they will determine the breadth of the ſide pieces; and by ſetting off from D to B, the length of the caſcable, and from C to A, half the diameter of the trunions and half the diameter of the fore trucks; then will A B be the length of the carriage.

The line E F paſſes through the center of the trunion holes, which are a caliber. and whoſe center is a quarter of an inch below the upper ſurface of the ſide pieces. On each ſide of GH ſet off 6 inches for the breadth of the axletree, which is always 12 inches broad; and the fore part of the trunion holes is the center line of the fore axletree, whoſe dimenſions, as well as thoſe of the trucks, are given in the following table.

Fig. 16.

The height of the ſide pieces is $4\frac{3}{4}$ diameters of the ſhot before, and half that height behind; and if half the length of the ſide.pieces be divided into four equal parts, beginning at the hind end, you will have the ſteps; the quarter-round is taken from the fore part. The lower part of theſe pieces is hollowed in the form of

of a circular arc, in order to make them something lighter without diminishing their strength. Both axletrees are sunk into the side pieces in the manner represented in the 17th figure; and as to the transom, we chuse to place it directly over the fore axletree, it is a diameter of the shot broad, and two high, and placed exactly in the middle of the height of the side pieces; though it is customary to place the fore part in a line passing through the center of the trunion holes, and so as to project the axletree by an inch, and the lower edge to touch the axletree.

Dimensions of ship and garrison carriages.

Nature of the gun,		42	32	24	18	12	9	6	3
Width inclosed	before	18	18	16.5	15.5	14	13	11.5	9
	behind	23.5	23.5	22.5	21.5	19.5	18.5	16.8	12.5
Fore axletree length		57	57	54.5	51.5	45.5	42.5	38.8	32.5
Body	length,	35.4	36.6	34.9	33.1	29.5	27.5	24.8	19.5
	height,	10.8	10.8	10	10	10	9.5	9	8.5
	breadth,	6.8	6.8	6.8	6	5.5	5.2	5	4
Arms	length,	10.8	10.2	9.8	9.2	8	7.5	7	6.5
	diameter,	6.2	6.2	6.2	5.8	5.2	5.	4.5	3.5
Hind axletree length,		57	57	54	51.5	45.5	42.5	38.8	32.5
Body	length,	35.4	36.6	34.9	33.1	29.5	27.5	24.8	19.5
	height,	6.8	6.8	6.8	6	5.5	5.2	5	4
	breadth	12	12	12	12	12	12	12	12
Fore trucks,	diameter,	19	19	18	18	16	16	14	14
	breadth,	6.5	6	5.5	5	4.5	4	3.5	3
Hind trucks,	diameter,	16	16	16	15	14	14	12	10
	breadth,	6.5	6	5.5	5	4.5	4	3.5	3
Side pieces	height before,	26.8	26.2	26	23.6	20	18.8	16	13.6
	length,	78	78	72	69	66	63	60	37.5
	breadth,	6.5	6	5.5	5	4.5	4	3.5	3
Trunions from the head,		8	8	8	8	6.8	6.6	6.6	6

These

These dimensions are expressed in inches and decimals; and as the arms of the hind axle-tree have the same dimensions as those of the fore ones, they have been omitted, as well as the height behind the side pieces.

It may be observed, that these dimensions were used in 1748; but if the guns are made different from those at that time, the length and width of the carriages will likewise differ. The height of the side pieces and the diameter of the trucks depend on the height of the port-holes in ships from the deck. Those of the lower tiers ought to be such, that when the breech of a gun lies upon the hind axle-tree, the muzzle of the gun should touch above the port-hole, in order that it may not push the shutter open when the ship rolls in stormy weather.

General construction of carriages for new Guns.

We suppose the diameter of the shot to be divided into 24 equal parts, as in the construction of the gun, so that the guns and their carriages may be constructed by the same scale; which is both more methodical and easier for the reader and the artillerist.

This being supposed; take CD equal to 6 diameters of the shot and 10 parts; and CE, CF, each equal to 34 parts, as likewise DG, DH, each equal to 39.5; the breadth of the side pieces is a diameter or 24 parts; DB to a diameter and 12 parts; AC to 2.5 diameters. The breadth of the fore axle-tree is 30 parts, its length $6\frac{1}{3}$ diameters; the length of the arms 44 parts, and their diameter 24. In the elevation, the height before of the side pieces is $4\frac{3}{4}$ diameters, and behind half that height; the height of the fore axle-tree is 42 parts, that of the hind one 30; the bed bolt passes under the middle of the fourth step, and even with the list or hind step.

The breadth of the wooden trucks is always equal to that of the side pieces, which is here one diameter or 24 parts; the diameter of the fore ones 4 diameters, and

and that of the hind 3 diameters and a half: but we have observed before, that if the port-holes in ſhips are made higher or lower, theſe diameters muſt be increaſed or diminiſhed.

The *French* make uſe of a carriage on board of ſhips with two trucks before only, and are preferred by many officers to thoſe of 4: I had ſome of them made, which ſeem to anſwer very well; they are nearly of the ſame height before as the common; but to leſſen the great height of the ſide pieces, the trucks are made of a larger diameter; they have no ſteps, and behind have a tranſom for the ſtool-bed to reſt upon inſtead of the body of the hind axle-tree. Theſe carriages do not recoil ſo much, and are more readily pointed, becauſe the trucks are not tight to their axle-tree. When they are traverſed but a little, the carriage will move without the truck, and then fall back again ſo ſoon as the handſpike is taken away.

The *French* garriſon carriages are made much in the ſame manner; but the trucks are made larger and of ſeveral pieces, and have a trail like travelling carriages, but much ſhorter.

Fig 17.

This elevation ſhews the inſide of the ſide pieces, with ſome of the irons, not elſe to be ſeen, and the manner we would have the ſide pieces let into the axle-trees, which is more ſimple, and yet equally as ſecure as the common manner, as likewiſe how the tranſom is to be placed, and not obliquely as the cuſtom is. The reſt of the figures in this plate ſhew the plans and elevations of the axle-trees and the ſtool-bed, as well as the tranſom.

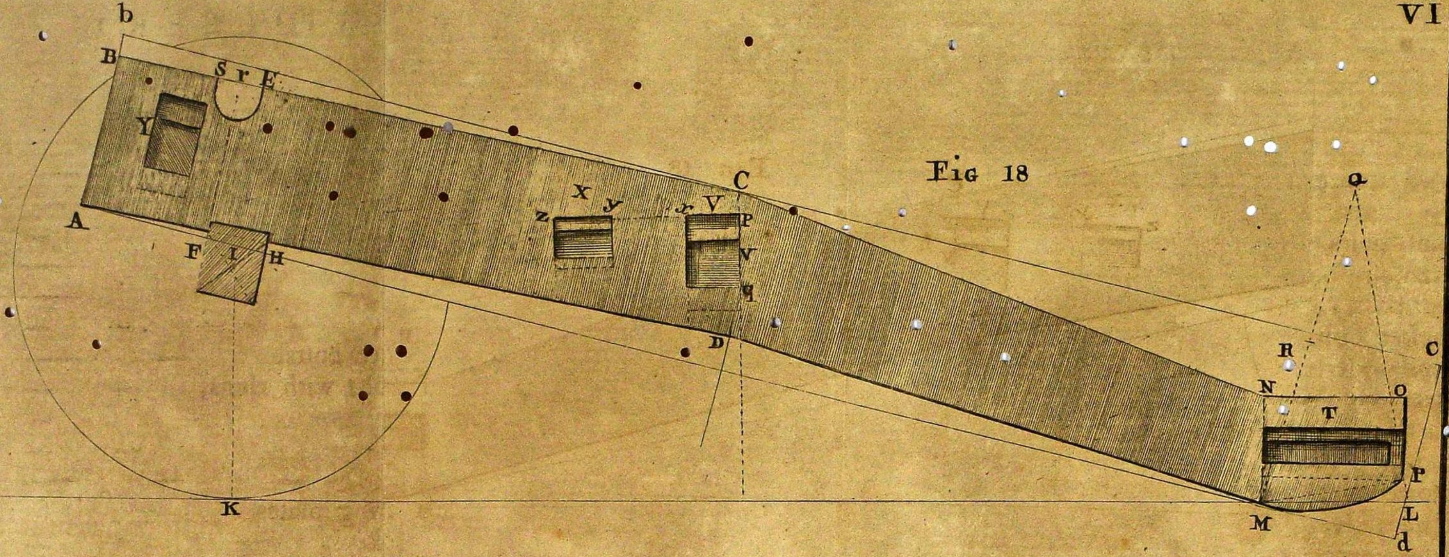

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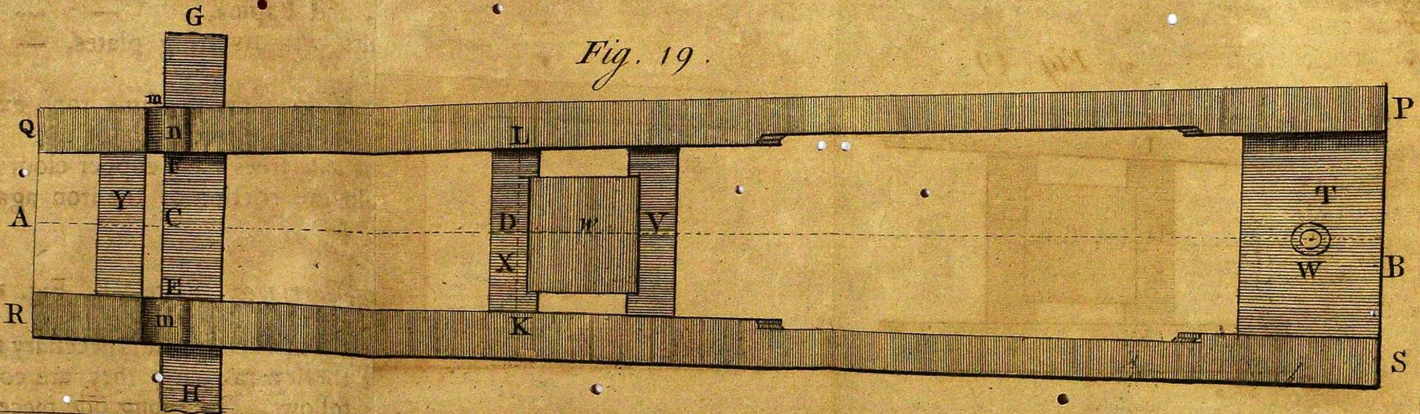
Fig. 19.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Irons for ship Carriages.

a.	Cape squares, — — —	2
b.	Eye bolts, — — —	2
c.	Joint bolts, — — —	2
d.	Transom bolt, — —	1
e.	Bed bolt, — — — —	1
f.	Bracket bolts, — — — —	2
g.	Hind axle-tree bolts, — —	4
h.	Breeching bolts with rings, — —	2
k.	Burrs, — — —	2
l.	Loops, — — — —	6
m.	Dowel pins, — — —	4
n.	Square rivetting plates, — —	8
p.	Rings with keys, — — —	10
q.	Traversing plates, — — —	2
r.	Linch pins, — — —	4
s.	Axle-tree hoops, — — —	2
t.	Axle-tree stays, — — —	2
w.	Keys, chains, and staples, — —	2
x.	Stool bed bolts with rivetting plates, —	2

The garrison carriages have the same irons, excepting the breech rings, and their trucks are of cast iron; for which reason their axle-trees have copper clouts underneath, to diminish the friction of the iron against the wood.

Of travelling Carriages. Plate VI. Fig. 19.

Previous to their constructions, it is necessary to mention the names of the several parts they are composed of, which are as follows. The long side pieces Q P, R S, are called the Cheeks; the fore part Q R of the carriage, the Breast; and the hind part P S, the Trail; T, the Trail Transom; V, the Center Transom; X, the Bed Transom; and Y, Breast Transom; GH, the

 Body

Body of the Axle-tree; m, n, the Trunion Holes; and w, the Pintle Hole.

Dimensions of the present Cheeks.

Nature of the gun,	24	12	6	3
Length of the cheeks,	13	12	11	10
Thickness,	5.8	4.6	3.6	3
Height of the plank,	22	19	16	13
Height of the cheek, before,	20	17	14	11.5
Height of the cheek, center,	17	15	12	9.5
Height of the cheek, trail,	12	11	10	7.5
Head from the center,	74	69	60	51.5
Length of the trail,	18	15	12	10

Axle-trees.

Nature of the gun,	24	12	6	3
Body, length,	38.5	39	40	40.5
Body, breadth,	7	6.5	6	5.5
Body, height,	9	8.5	8	7.5
Arms, length,	21	20.5	19	17.5
Arms, body diameter,	7	6.5	6	5.5
Arms, linch diameter,	5	4.5	4	3.5
Total length	81	80	78	76

N. B. The under part of the axle-tree ſhould be in one continued right line, as we have ſhewn in our *Elements of Mathematics.*

All the dimenſions in the preceding tables are in inches and decimals, except the length of the cheeks, which are in feet.

Conſtruction of travelling Carriages. Plate VI. Fig. 18.

Let A b c d be the plank, and AB the height before of the cheeks; ſet off from B to C the ſum of the head A B, and the diſtance from the hind part of the trunions

trunnions to the extremity of the caſcable; then from the point A as center, deſcribe an arc CD through the point C, on which as a chord ſet off the height at the center, and draw the lines A D, B C. On B C take B E, equal to the head A B, and towards the head E r, r S, each equal to half the diameter of the trunnions, ſo that E S will be the width of the trunnion hole, whoſe center is about a quarter of an inch below the line B C. From the point r draw r F, perpendicular to A D; in AD take FH, equal to the breadth of the axle-tree, which is ſunk about an inch into the cheeks. On the ſide FH make a ſquare, and from the interſection I of diagonals, as center, deſcribe an arc, with a radius of 29 inches, or equal to the radius of the wheel; this arc will repreſent a part of the wheel. Then if a ruler be laid ſo as to touch this arc, and cut the plank in two points M L, ſuch that the diſtance M L be equal to the length of the trail, and you erect at theſe points two perpendiculars M N, L O, to K M, each equal to the height of the trail; by drawing the lines C N, N O, and D M, you will have the figure A B C N O L D A of the cheek required.

The part M P is made round, that the carriage may ſlide with more eaſe on the ground, which is done by dividing LO into four equal parts, ſo that L P be one of them, by drawing M P; and at the points M and P, erecting two perpendiculars on D M, and on M P, which meeting in Q, then the point R, which biſects M Q, will be the center of the arc M P required.

The mortiſe V of the center tranſom is determined by drawing a line through the point C, perpendicular to the horizon K M, in which C p is taken equal to a fourth part of the ſhot's diameter, and p q equal to two of theſe diameters for the height, and in p z, parallel to K M, the breadth p x equal to one diameter. The diſtance between the center and bed tranſom X is two diameters; this laſt is a diameter each way. The breaſt tranſom Y is a diameter broad and two high; the ſides are

are parallel to the head A B, and terminate above even with the bottom of the trunnion hole one way, and when produced the inside meets the point S. Lastly, the mortise T of the trail transom is equal in length to the trail, a diameter high, and is parallel to the upper side N O, so as when the lower is produced to meet the point P.

All these mortises are divided into four equal parts by horizontal lines; the upper part is sunk half an inch into the cheeks; the two middle parts are sunk to the depth of two thirds of the thickness of the cheeks, but the lower part is not sunk in at all. They are made in this manner to prevent the wet from getting into the joint and rotting the tenons.

Construction of the plan. Fig. 19.

Draw the indefinite line A B, in which take the points C D, so as their interval be equal to the distance from the center of the trunnions to the extremity of the base ring; through these points draw EF, KL, at right angles, to A B; make D K, D L, each equal to the radius of the base ring, and C E, C F, each equal to the radius of the second reinforce ring; then the lines drawn through the points F, L, and E, K, will determine the width within of the carriage; if to these lines two others are drawn parallel, and at a distance equal to the length of the trunnions, you will have the thickness of the cheeks Q P and R S.

On both sides of the points E and F, set off half the diameter of the trunnions, in order to have the trunnion holes m, n; draw the breast transom Y of a diameter broad, so as the inside be in a line with the fore part of the trunnion holes; and if C A be taken equal to r B in the last figure, the line R Q at right angles to A B will determine the breast of the carriage, and the total length AB of the carriage is determined by the last figure.

If

If you ſet off from the line K L two diameters for the length of the caſcable, you will have the hind part of the center tranſom V, whoſe width is a diameter as well as the bed tranſom X, and their interval is two of theſe diameters, as has been ſaid before; the trail tranſom T is determined as before by the length of the trail. In the middle of this tranſom is the pintle hole of an oval figure, wider above than below, that the pintle may have room to play on uneven ground.

The bed w is a board of an inch and a half thick, a foot broad, and ſunk into the bed and center tranſoms; the width of the axle-tree has been determined before, and its fore part paſſes through the centers of the trunnion holes: there is a board fixed upon the axle-tree with one end, and the other upon the bed tranſom, which ſerves to lay hay or ſtraw upon for wadding.

Between the trail and center the breadth of the cheeks is diminiſhed on the inſide by a ſixth part, beginning at about a diameter from the trail, and ends within a diameter and a half from the center tranſom.

This is the common conſtruction of field carriages; but as it relates only to the four calibers, whoſe dimenſions have been given, the reader will ſtill be at a loſs how to conſtruct any other; and as the length of the cheeks depends not only on the caliber of the gun, but likewiſe on the height of the wheels, as well as on the length of the pieces, which varies very often: therefore, in the following conſtruction, we ſuppoſe the wheels of the common ſize, and the guns to be 20 or 21 diameters long, which is the common length at preſent of the 24 pounders.

General dimenſions of travelling Carriages. Fig. 18.

The length A d of the plank is 12 diameters of the ſhot and 7.5 feet beſides; its height A b three diameters and three quarters; the height A B of the cheeks three diameters and a quarter; ſo that B b is half a diameter, the height

height DC at the center 70 parts of that diameter, divided into 24 equal parts, as in the conſtruction of guns; the length of the trail is three diameters, and its height MN two; the breadth FH of the axle-tree is two diameters, and the reſt of the dimenſions depend on the ſize of the gun.

General Conſtruction of travelling carriages for the new Guns.

Plate VI. Fig. 18.

The length A d of the plank is 10 diameters of the ſhot, and 7.5 feet; its height A b, three diameters and three quarters; the height A b of the cheeks, three diameters and a quarter. Set off from B to C eight diameters, and twenty parts of that diameter divided into 24, as in the conſtruction of guns; then from the point A, as center, deſcribe an arc through the point C, on which, as a chord, ſet off 70 parts from C to D, and draw the lines A D, B C. On B C take B E, equal to the head AB, and towards the point B, the parts E r, r S, each equal to 9 parts, ſo that E S will be the width of the trunnion holes, whoſe center is ſunk about a quarter of an inch into the cheek. From the point r draw r F, perpendicular to A D, and in A D take F H equal to 30 parts for the breadth of the axle-tree, which is ſunk into the cheek about an inch. On the ſide F H make a ſquare, and from the interſection I of the diagonals, as center, deſcribe an arc with a radius of 29 inches, which arc will repreſent a part of the wheel. Now if a ruler be laid ſo as to touch this arc, and cut the plank in two points M, L, ſo that the diſtance M L be equal to three diameters, and there be erected at theſe points the perpendiculars M N, L O, to K M, each equal to two diameters, then, by drawing the lines C N, N O, and D M, you will have the outline A B C L D A of the cheeks. The under part of the trail is made round,

round, and the mortises of the transoms are made as before.

Construction of the plan. Fig. 19.

Draw the indefinite line A B, in which take the points C, D, so as their interval be 7 diameters and 17 parts; through these points draw E F, K L at right angles to A B; make D K, D L, each equal to 32.5 parts, and C E, C F, each equal to 27.5 parts; then the lines drawn through the points F, L, and E, K, will determine the width within of the carriage. If to these lines two others are drawn parallel, and at 18 parts distant, you will have the thickness of the cheeks, Q P and R S.

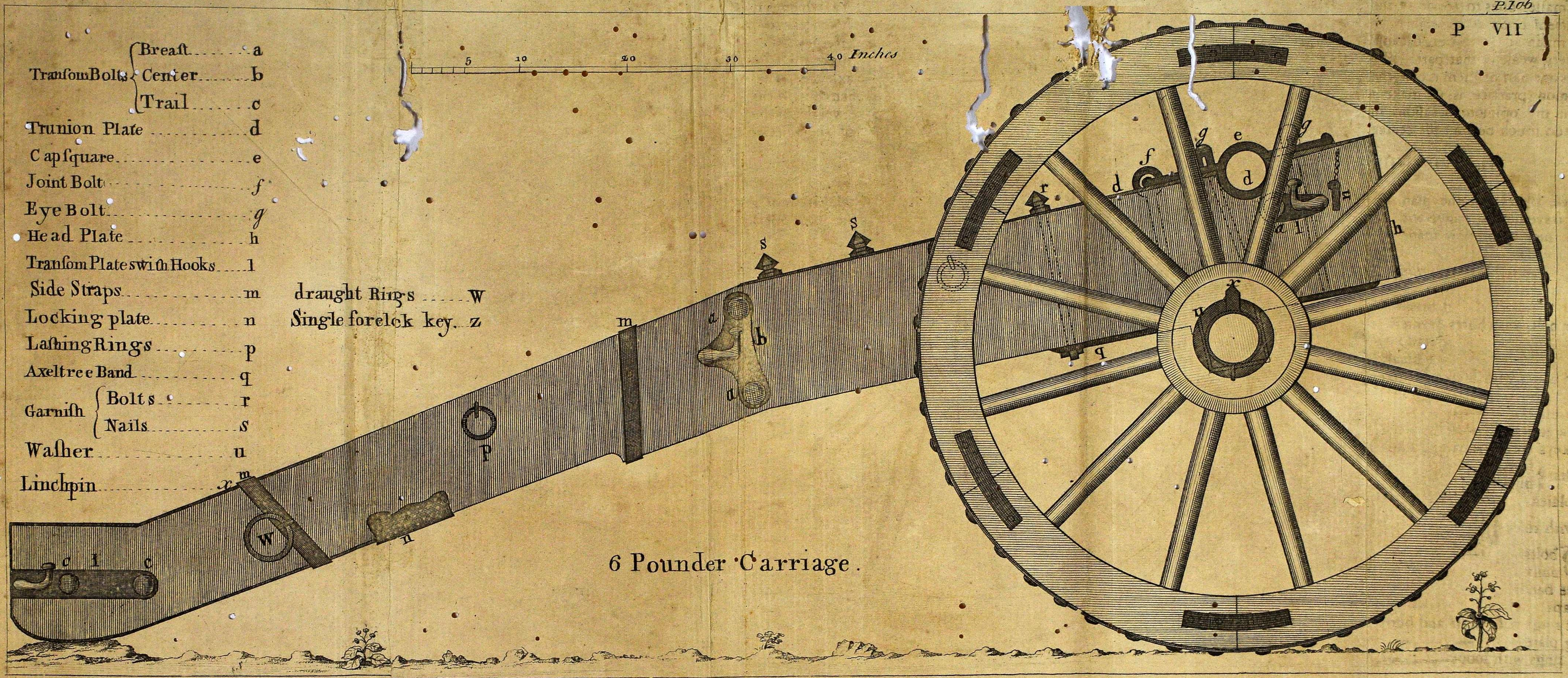
On both sides of the points E F, set off 9 parts for the radius of the trunnions, in order to have the trunnion holes m, n. If C A be taken equal to r B in the last figure; the line R Q, drawn at right angles to A B, will determine the breast of the carriage, and the total length A B is determined by the last figure. The rest of the construction is the same as before.

Remarks on this construction.

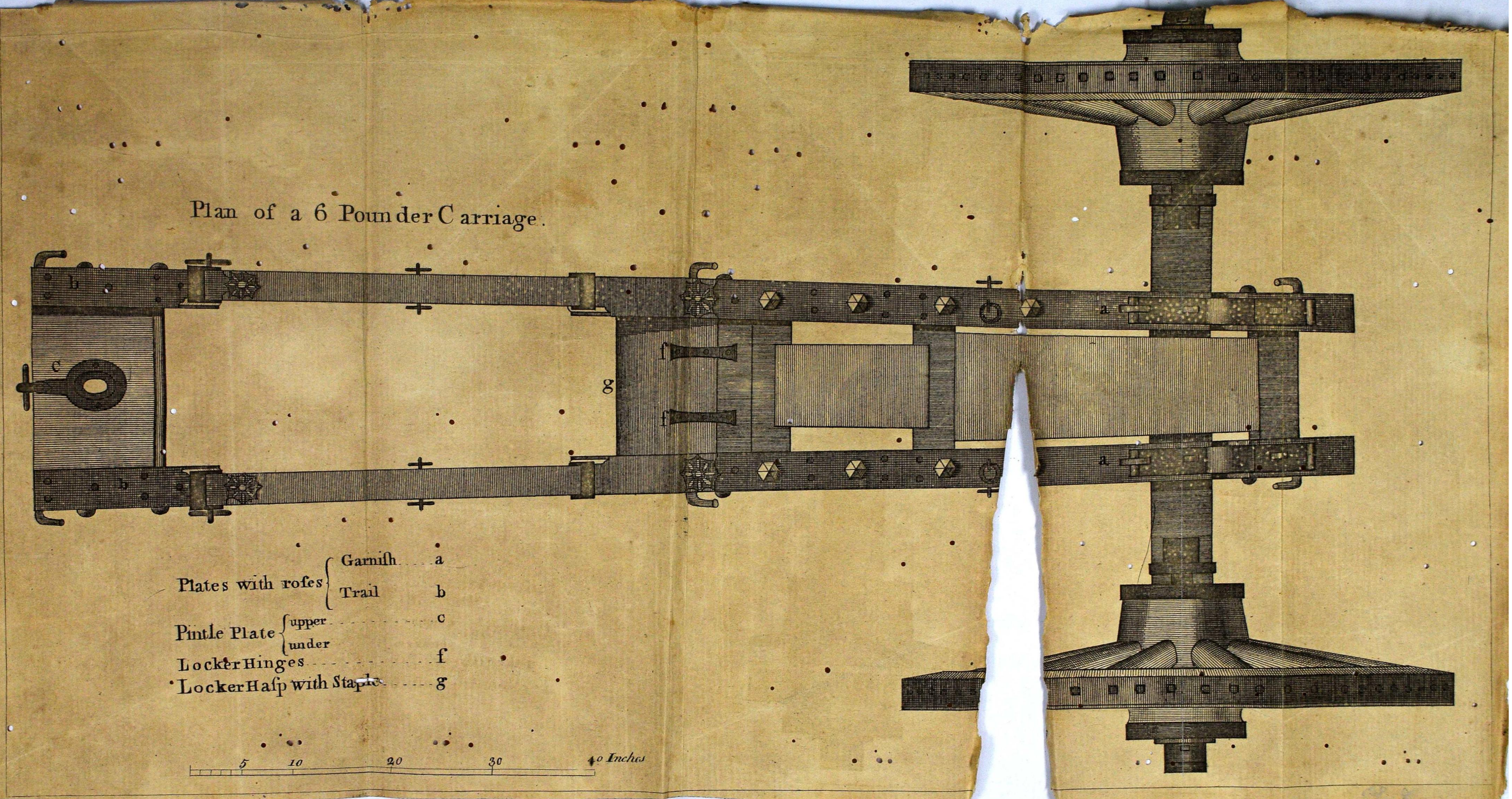
Regard must be had in the construction of these carriages to their strength, and that the piece may lay close and steady in it; as likewise that the gun may be properly elevated, in case ricochet firing should be required.

The thickness of the cheeks are here supposed eighteen parts instead of a caliber, as is usual; this we esteem sufficient; because pieces are now loaded with no more than one third of their shot's weight, or ought not at least; which charge has been found sufficient for battering pieces.

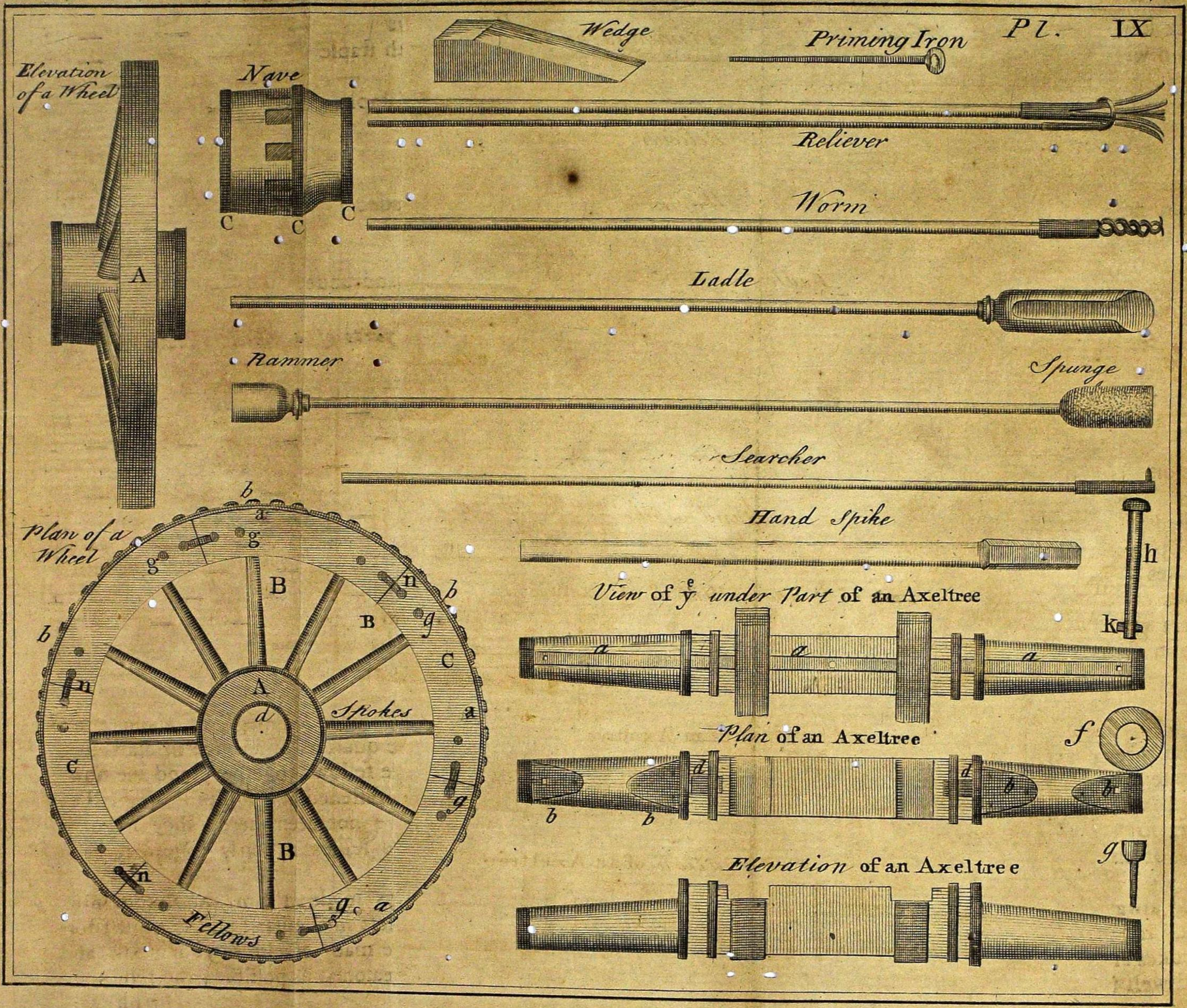
The length of these carriages is such, that a 24 pounder may be elevated to about an angle of 9 degrees, and



6 Pounder Carriage.



Plan of a 6 Pounder Carriage.
a
a
b
b
c
f
f
g
Plates with roses { Garnish ..... a
Trail ..... b
Pintle Plate { upper c
under
Locker Hinges ..... f
Locker Hasp with Staple ..... g
5 10 20 30 40 Inches


Pl. IX
Wedge
Priming Iron
Elevation of a Wheel
Nave
Reliever
Worm
Ladle
Rammer
Spunge
Searcher
Hand Spike
Plan of a Wheel
Spokes
Fellows
View of ye under Part of an Axeltree
Plan of an Axeltree
Elevation of an Axeltree

Single forelock keys — — —	8
Bed piece chain with ſtaple — —	1
Locker { hinges — — —	2
Locker { haſp with ſtaples — —	1
Wood ſcrews	
Rivets	
Nails { roſebuds	
Nails { diamond headed	
Nails { counterſunk	
Nails { trail	
Pintle plates upper and under — —	1

Names of the parts of a wheel. Plate IX.

A. Nave — — — —	1
B. Spokes — — —	12
C. Fellies — — — —	6
n. Dowel pins — — —	6
a. Streaks — — — —	6
b. Streak nails — — — —	48
c. Nave hoops — — — —	3
d. Nave boxes — — — —	2
f. Dowledges — — — —	6
g. Rivets for ditto — — — —	24
h. Nave hoop ſtubs — — —	9
k. Box pins — — —	6

The dowel pins are wooden pegs, of about three inches long, and three quarters of an inch in diameter; they ſerve to faſten the fellows together; and the dowledges are iron plates, faſtened and ſunk into the fellies on the outſide, ſo are not ſeen here; they ſerve to bind the joints of the fellies ſtrongly together, each with four pins.

The nave is always made of elm, cut ſix months before it is uſed, and left in the bark all the while till it is uſed; the ſpokes are made of elm or young oak, and uſed as dry and well ſeaſoned as poſſible; the fellies are likewiſe

likewise made of dry elm, or in default of which young beech split in two only will do as well, if not better; and the axle-tree is made of dry elm, young oak, or young beech.

The cheeks and transoms are always made of dry elm, on account that this wood is very pliable, receives the nails better than any other, and does not split; yet I have seen some made of young oak, and am of opinion it is much stronger than elm, and I think may answer better.

Dimensions of wheels for travelling Carriages.

Caliber		24	22	6	3	Parts
Wheel, diam. inches		58	58	58	58	
Nave, length		17.5	17	15.5	15	76
Diameter	body	15	15	13	12.5	62
	middle	16	16	14	13	74
	linch	13.5	13.5	10	10	60
Fellies	thickness	5	4.5	4	3	22
	breadth	6.5	6	5.5	4.5	28
Spokes	thickness	2.3	2.2	2.1	2	10
	breadth	4.5	4	3.5	3	20

The mortises of the spoke should be placed in the middle of the nave, but the workmen make them an inch nearer to the linch. The spokes are somewhat less near the fellows than at the nave; they are likewise inclined towards the linch three inches in a wheel five feet high, and so in proportion in one of any other diameter; which the workmen call *dishing*. How they found out that this inclination renders the wheels more perfect is not easily known; those that I have conversed with knew no more than that it was an old custom, which made me inquire farther into it, and I have found that it is grounded on true mechanical principles, as may be seen in my *Elements of Mathematics*, page 245.

The

The laſt column in the preceding table contains the general dimenſions of the reſpective parts for wheels of any ſuch carriages, expreſſed by the parts of the diameter of the ſhot divided into 24, as in the conſtruction of guns, and proportional to the dimenſions of a wheel for a 24 pounder's carriage. Theſe general dimenſions are very uſeful in ſeveral reſpects: ſuppoſe it were required to make wheels for any other calibers than thoſe above, then you muſt either refer thereto, or elſe perform the work by gueſs. Again, theſe dimenſions being expreſſed by the ſame parts as the guns, they may both be conſtructed upon the ſame ſcale; which cannot be done in the common manner without a great deal of labour and difficulty: in ſhort, artillery would be incomplete without them; becauſe it is not ſufficient to know how to execute what has been done before, but any other work of the ſame kind that may be neceſſary.

The *Span*, or interval between the wheels, varies in different countries; even every county in *England* obſerves a different width, which is very inconvenient for thoſe who travel in carriages. The artillery carriages are made like thoſe in *Flanders*, which is four feet eight inches; but as the fellies are not of the ſame breadth in all wheels, we ſhall make the diſtance between the middle of the fellies five feet in all the carriages uſed by land, which are hereafter mentioned, the truck one excepted.

Iron-work of an Axle-tree. Plate IX.

a. Axle-tree bar		1
b. Clouts	body	2
	linch	2
c. Axle-tree hoops	linch	2
	arms	2
	body	2
d. Hurters with ſtraps		2
f. Waſhers		2

g. Linch

g. Linch pins — — —	2
h. Axle-tree bolt — — —	1
k. Single forelock — — —	2
Clout nails — — — —	12
Dog nails — — —	8

Tools neceſſary to prove and load Guns.

The ſearcher is an iron ſocket with branches, from four to eight in number, a little bent outwards, with ſmall points at their ends: to this ſocket is fixed a wooden handle, from 8 to 12 feet long, of about an inch and a quarter diameter. This ſearcher is introduced into the gun after it has been fired, and turned round, to diſcover the cavities within; and after their diſtances are marked on the outſide with chalk, they make uſe of another ſearcher, that has only one point, about which a mixture of wax and tallow is put to take the impreſſion of the holes; and if there are any of a quarter of an inch deep, or of any conſiderable length, the gun is rejected as unſerviceable to the government; though the iron is ſold to merchants. The gun is thus proved and ſearched twice.

The reliever is an iron ring fixed to a handle by means of a ſocket, ſo as to be at right angles; it ſerves to diſengage the firſt ſearcher, when any of its points are retained in a hole, and cannot otherwiſe be got out.

The worm is a double-wired ſcrew, fixed to a handle by means of a ſocket; it ſerves to draw out the wadding or bottoms of cartridges which remain in the gun after frequent firing, and which would otherwiſe accumulate ſo much, that other cartridges could not be rammed home enough to reach the priming, whereby the gun would miſs fire.

The ladle is made of copper, about three diameters of the ſhot long, and the thickneſs equal to the windage of the gun: it is of a cylindric form, having an opening above of about a ſixth part of the circle, and made like

like a ſcoop at the end. The uſe of the ladle is to introduce the charge of powder into the gun, when it is not made up into a cartridge, or to looſen the ſhot, and draw it, in caſe it is retained by duſt got into the gun after much travelling.

The rammer is a cylinder of wood, whoſe diameter and length are each equal to the diameter of the ſhot, with a handle fixed to it; it ſerves to ram home the ſhot and powder when the gun is loaded.

The ſponge is likewiſe a cylinder of wood, from 10 to 12 inches long, of the ſame diameter with the rammer, and covered with lambſkin, ſo as to fit the gun exactly; it is commonly fixed to the other end of the rammer's handle in ſmall guns, but has a ſeparate one in thoſe of larger calibers. The uſe of the ſponge is to clean the piece before and after it is fired. The IXth plate repreſents the forms of theſe tools, whereby the reader may have a clear conception of them.

Guns are proved various ways, to find whether they are ſufficiently ſtrong; the moſt common in *England* is with a charge of powder, which weighs as much as the ſhot in all pieces under a 24 pounder; which, if braſs, is loaded with 21 pounds, the 32 pounder with 26 and 12 ounces, the 42 pounders with 31 pounds 8 ounces *; but in *France* they are charged with two thirds of the ſhot's weight only. Sometimes water is forced into them, but this proof is inſufficient; it has been found, that though the water penetrated through the piece in ſeveral places, yet they were very good and ſerviceable. The beſt and ſureſt way of proving pieces made after a new pattern, or of ſome new metal, is to charge them with no more powder than they are loaded with in action, and to fire them 2 or 300 rounds as quick as poſſible; and if they ſtand this trial, there is no danger of their

* The charge of the iron 24 pounder is 18 pounds; that of the 32 is 21 pounds 8 ounces; and the 42 is 25 pounds. As to the light braſs field pieces, they are proved with half the weight of the ſhot; except the 24 pounder only, with 10 pounds.

burſting

bursting afterwards. This has been done by our light 6 pounders, when they were first introduced into our service. Mr. *De Valliers*, lieutenant-general of the artillery in *France*, has proposed another method for proving pieces, which is, instead of loading them with shot, to ram clay in as hard as possible two feet deep. But I doubt whether an iron cannon could stand such a proof, nor would I advise the trial.

To construct field Carriages. Plate X.

As field pieces are shorter and much lighter than those above, their carriages likewise observe the same proportion. They have the same form, but their wheels are only four feet two inches high; which, in my opinion, is too low; for the draught of low wheel carriages is known to be greater than the higher: and though the guns are light, yet that is no reason to make the draught greater. I think, if they were 4.5 feet high, it would be much better; but it being no easy matter to change any thing established by custom, we shall insert the dimensions used at present, that the reader may see what has hitherto been the practice, leaving my observations to his judgment, either to approve or not, as he pleases.

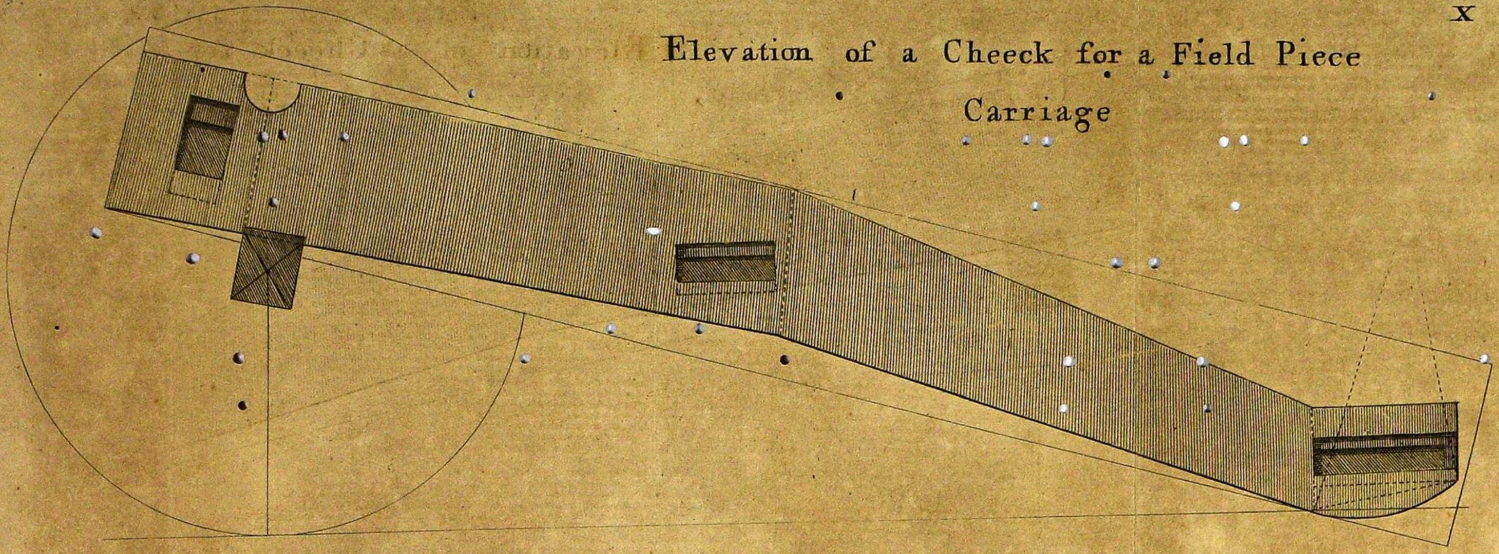
Dimensions of field Carriages.

Calibers	24	12	6	Parts
Length of the plank	108	106	94	13 : 4
Height of the plank	15.6	14	12.4	3 : 6
Thickn. of the plank	4.5	3.7	3	0 : 18
Cheeks, height before	14.5	12.7	11	2 : 18
Height at the center	12	10.9	9.8	2 : 16
Height at the trail	10	9.2	8.4	1 : 16
Length of the trail	11	10.5	10	1 : 22
From head to center	10	45	40	11 : 6
Width within before	11.5	10.7	10	2 : 1
Width within behind	17	15	13	2 : 15

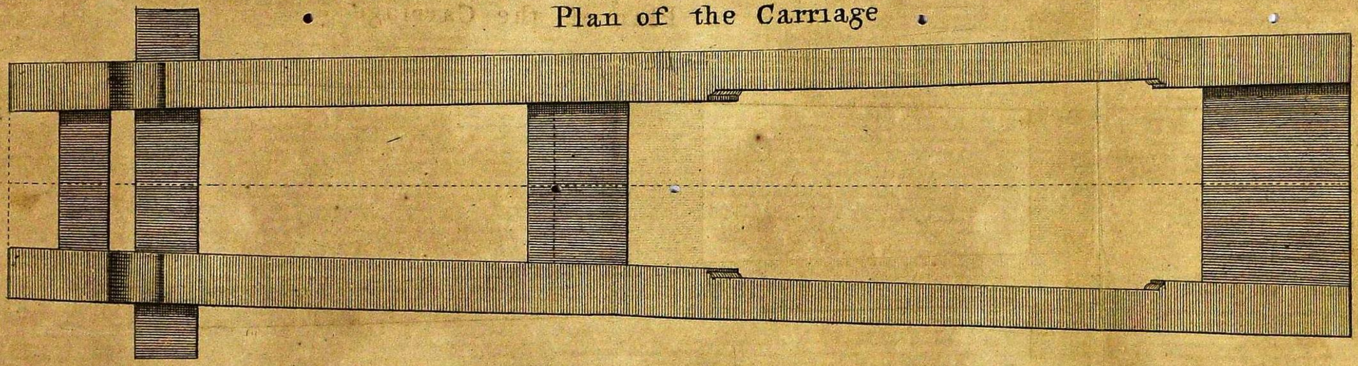
Dimensions

X

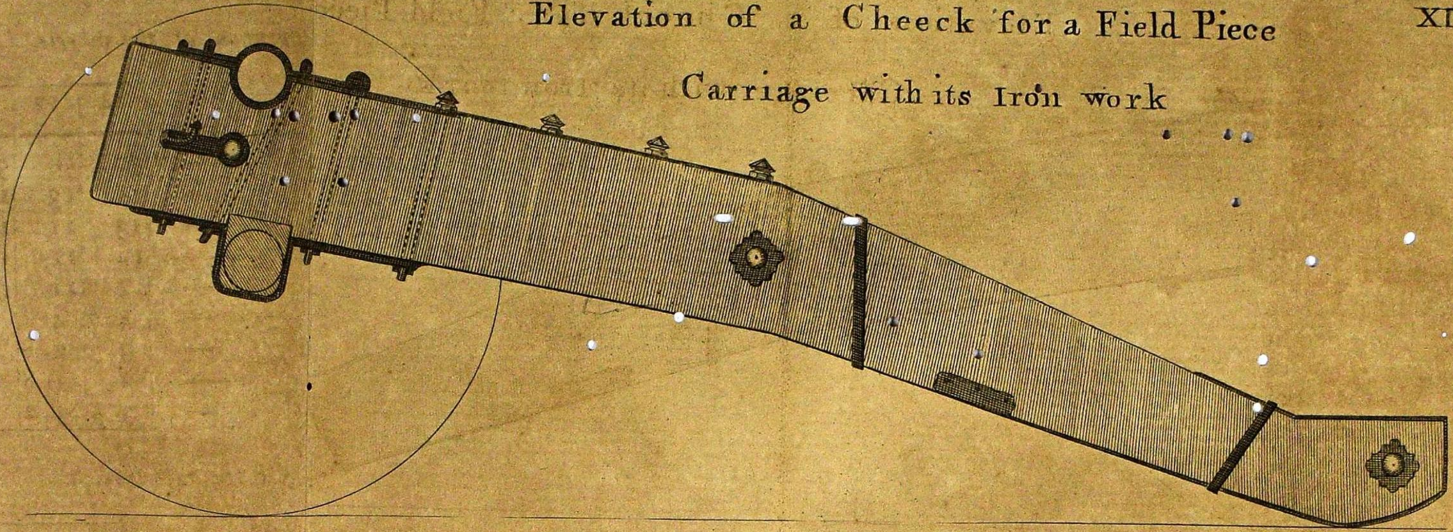
Elevation of a Cheeck for a Field Piece Carriage



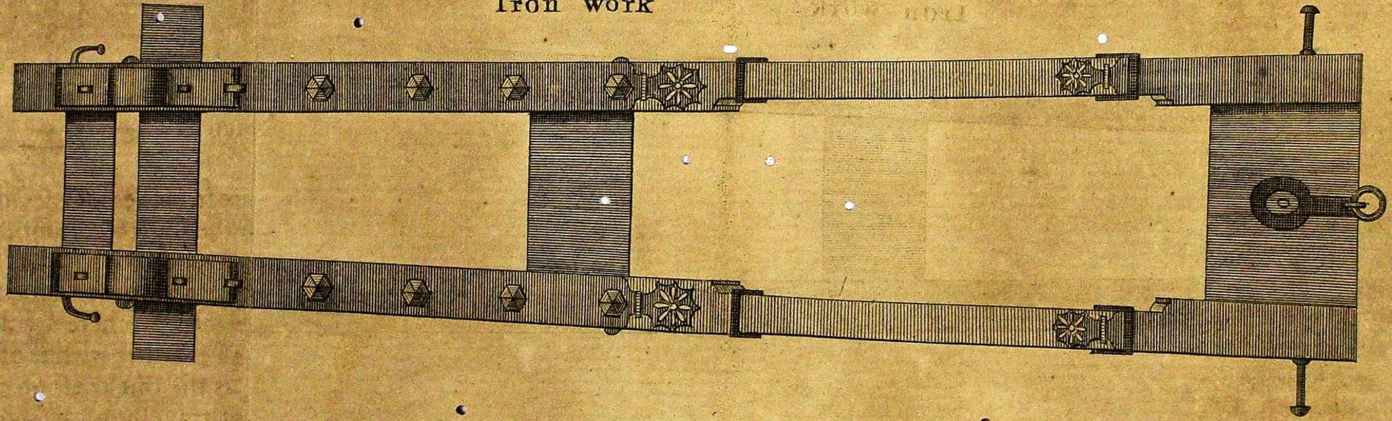
Plan of the Carriage



Elevation of a Cheeck for a Field Piece Carriage with its Iron work



Plan of ye Carriage with its Iron work



Dimensions of the wheels.

Caliber	24	12	6	Parts
Wheel, height	50	50	50	
Nave, length	15	13	12. 7	3 : 0
Diameter body	13	11	10. 6	2 : 10
Diameter middle	14	12	11. 6	2 : 15
Diameter linch	12	11	10	2 : 5
Fellows height	4. 7	4	3. 6	1 : 0
Fellows breadth	3. 3	2. 8	2. 4	0 : 16
Spokes breadth	2	1. 8	1. 7	0 : 9
Spokes thickneſs	3. 5	3. 2	2. 9	0 : 17

Of the axle-tree.

Caliber	24	12	6
Axle-tree, length	68	72	76
Body length	39	40	42
Body breadth	6	5. 5	5
Body height	8	7	6
Arms, length	18	16	15. 7
Diameters body	6	5. 5	5
Diameters linch	4	3	3. 5

Theſe dimenſions are in inches and decimal parts, except thoſe general ones in the fourth column, which repreſent diameters of the ſhot and parts, the whole diameter being divided into 24, as in the conſtruction of guns. The length of the planks are here 13 diameters of the ſhot and four feet. The width within of theſe carriages may be more or leſs, as the thickneſs of metal is varied.

The conſtruction of travelling carriages given before, ſerves likewiſe for theſe, by making uſe of the laſt dimenſions inſtead of the former; the only difference is, that there is no bed tranſom here, becauſe ſcrews are

 uſed

used to raise these light pieces instead of wedges; for which reason the center transom is two diameters broad, and but one thick; it is placed in the middle of the height of the cheeks at the center, so that the neck of the cascable answers to the middle of the breadth of the transom, the screw being fixed there.

It must be observed, that on each side of these carriages is a locker or box of two feet long, its upper surface even with, or about an inch above the upper part of the axle-tree, extending from thence towards the trail; and its depth is equal to the height of the axle-tree. These lockers serve to hold shot upon a march, and are covered each by another box that slides on, and is fastened with a bolt, in which cartridges are lodged, to be ready for firing at any time, without having recourse to the ammunition carts.

The iron work of these carriages is nearly the same as in the former, only not so strong; and there is but one garnish bolt, which supports the fore part of the locker; and no garnish nail, though there are three marked by mistake in the XIth plate. The eye bolt next to the joint bolt passes through the axle-tree band behind, and not before as in other carriages; the fore part of this band is only fastened by the fore eye bolt. We have marked but one transom bolt at the center and one at the trail, though they make two at present in each of these places, which is superfluous; the *Saxon*, who brought these pieces into use here, made no more. The draught hooks are placed to the breast transom plates, instead of fixing them to the axle-tree, as practiced; because the horses draw with more strength when the hooks are nearly breast high. Lastly, instead of making hooks to the trail transom plates, there are substituted nails about four inches long, which we imagine are much more convenient than the former. The washers have also hooks, to which are fastened the ropes by which the gunners draw the gun along.

There

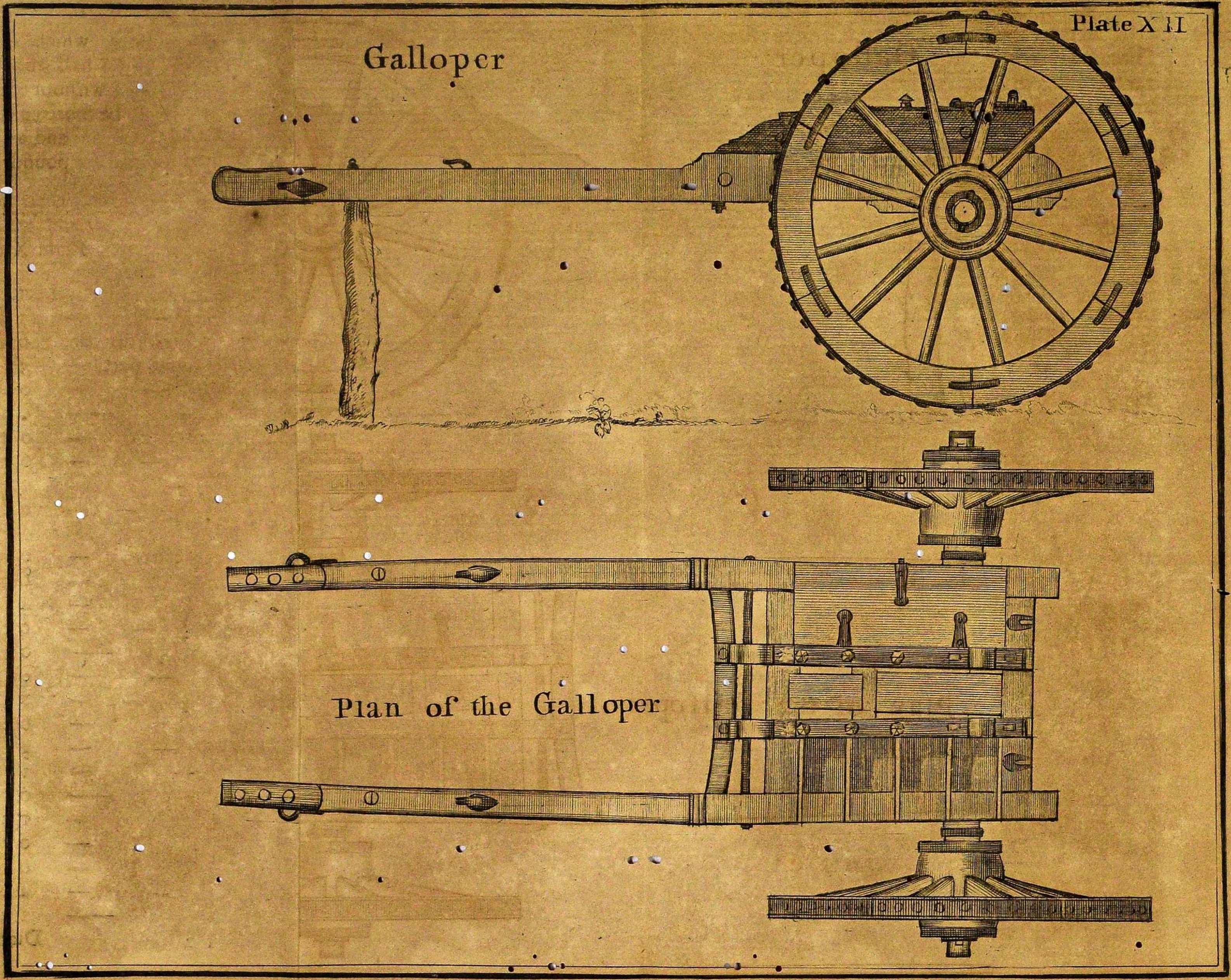


Plate XII
Galloper
Plan of the Galloper

There is one gun carriage more, which is called Galloper; it ſerves for a pound and a half gun. This carriage has ſhafts ſo as to be drawn without a limber, and is thought by ſome artilleriſts to be more convenient and preferable to other field carriages: and as it may likewiſe ſerve for our light three and ſix pounders, we ſhall give the following

Dimenſions of a galloper Carriage. Plate XII.

		Feet.	
Total length of the ſhafts,		11	0
From the	fore end to the fore croſs bar,	6	4
	hind end to the round part,	5	0
Height at the	hind end,	0	6
	fore end,	0	3
Breadth	behind and before,	0	3.5
	in the middle,	0	4.5
Width within behind,		2	6.5
At the fore	croſs bar,	2	4
	end	2	1
From the hind end to the axle tree,		0	11
Croſs bar from the hind end,		0	3
Length	of the cheeks,	4	2
Breadth	of the cheeks,	0	2.5
Height	of the cheeks,	0	6.5
Width within	before,	0	8
	behind,	0	11.5
Total length of the axle-tree,		6	4
Length of the	body,	3	6.5
	arms,	1	4.6
Breadth	of the body,	0	5
Height	of the body,	0	6
Greateſt	diameter of the arms	0	5
Leaſt	diameter of the arms	0	3.3
Diameter of the wheel,		4	3
Nave, length,		1	1

Diameters,	body,	0 : 11
	middle,	1 : 0
	linch,	0 : 10
Spokes,	breadth,	0 : 1. 5
	thicknefs,	0 : 3
Fellows	breadth,	0 : 5
	height,	0 : 4. 5

The dimenfions not inferted here may be taken from the draft.

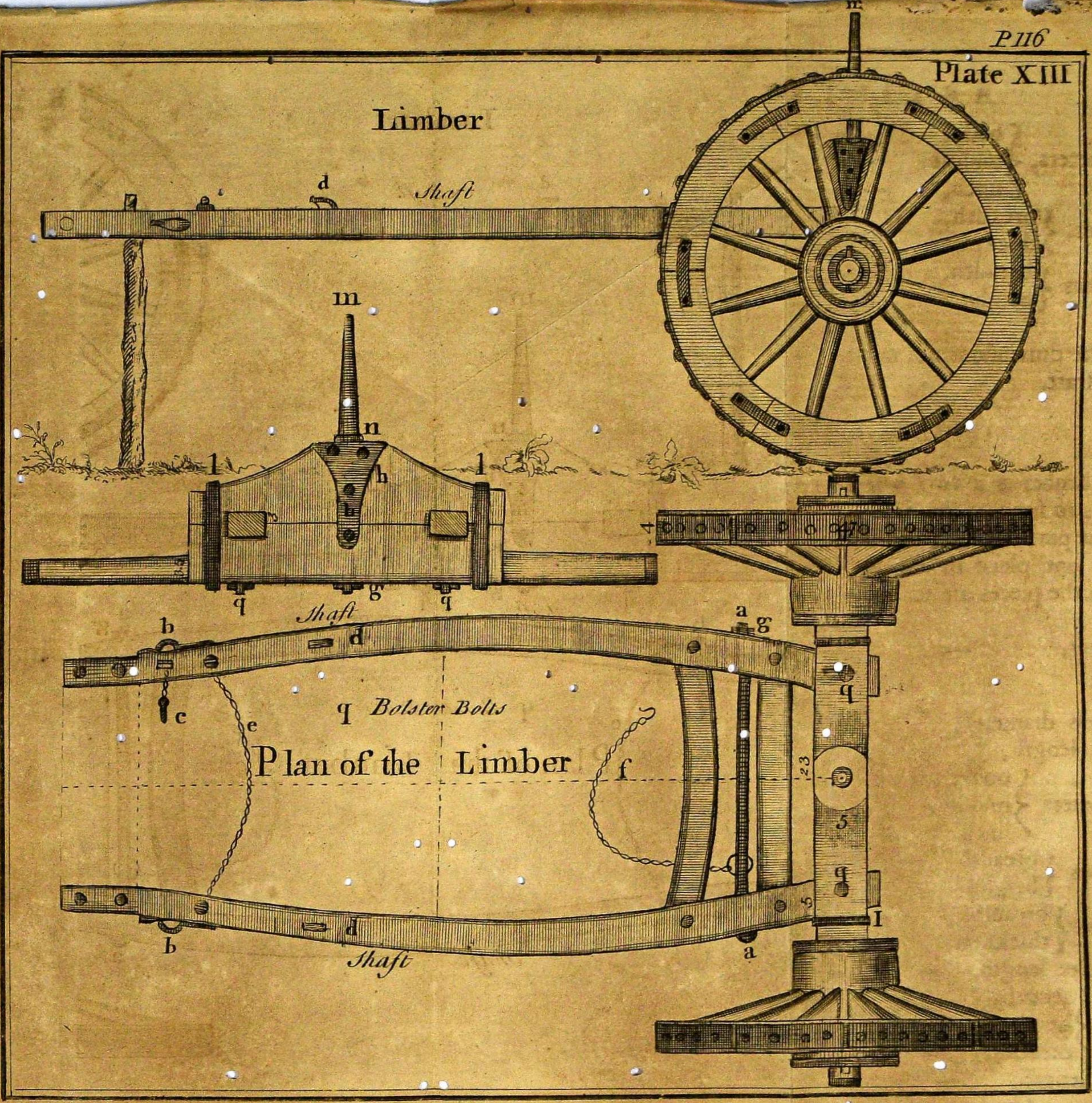
Of Limbers. Plate XIII.

A limber is a two wheel carriage with fhafts, and ferves to fupport the trail of field carriages, by means of the pintle or iron bolt, when they are to be drawn from one place to another; they are taken off again when the pieces are to be fired. Their dimenfions are,

Caliber,		24	12	6	3
		Inches			
Wheels diameter,		48	48	48	45
Nave length,		16	15	14	10
Diameters	body,	13. 5	13. 5	12	12
	middle,	14	14	13	12. 5
	linch,	12	12	11	10
Fellows	breadth,	4. 5	4	3. 5	3
	height,	5	4. 5	4	3. 5
Spokes	breadth,	1. 8	1. 6	1. 4	1. 2
	thicknefs,	4	3. 5	3	2. 5
Axle-tree length,		78	76	74	69
Body	length,	40	40	40	43
	height,	7. 6	7	6	5. 5
	breadth,	6	5. 5	5	5
Arms length,		19	18	17	13
Diameters	body,	5	4	4	4
	linch,	4	3	3	3
Shafts length,		94	94	94	94

Breadth

Plate XIII


Limber
Shaft
d
m
n
h
l
l
q
g
q
Shaft
b
d
a
g
q
c
e
q Bolster Bolts
Plan of the Limber
f
23
5
q
b
d
a
Shaft

Breadth	hind end,	6	5.5	5	4
	fore end,	3	3	2.5	2.5
Height	hind end,	3.3	3	3	3
	fore end,	3	3	2.5	2.5
Bolſter height,		12.5	10	8	7
Length,		40	40	40	43
Breadth,		6	5.5	5	5
Fore croſs bar	breadth,	4.5	4	3.5	3
	height,	1.5	1.5	1.5	1.5
Hind croſs bar	breadth,	3.5	3.5	3.5	3
	height,	1.5	1.5	1.5	1.5
Axle tree from the fore croſs bar,		11.5	11.5	11.5	11.5

All ſhafts are about two feet open before, two feet ten inches in the middle, and ſomething leſs near the axle-tree, according as the wood happens to be more or leſs crooked; for it is never cut acroſs the grain, becauſe that would weaken it too much. The bolſter diminiſhes towards both ends, as in the drafts; ſo that the height given here is to be meaſured in the middle.

Iron work of the ſhafts.

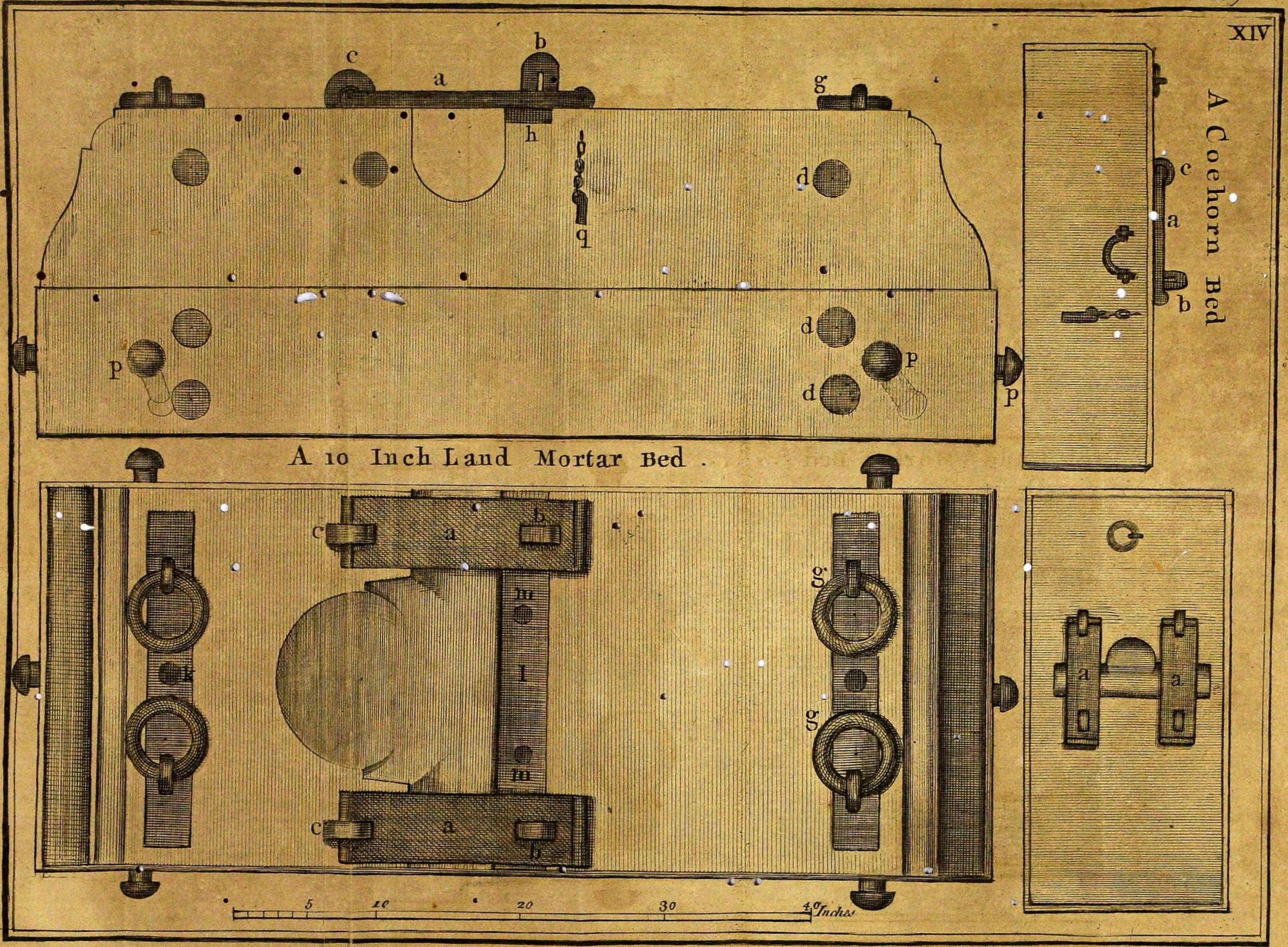
a. Limber bolt,	1
b. Shaft rings,	2
c. Shaft pins with chains,	2
d. Breech hooks,	2
e. Ridge chain with hook and loop,	1
f. Limber chain with hook and rings,	1
g. Single forelock keys,	4
h. Nails, diamond headed,	8
k. Dog nails,	6
l. Bolſter hoops,	2
m. Pintle,	1
n. Pintle waſher,	2
Stubs for bolſter hoops,	8

The iron work of the wheels and axle-tree being the ſame as before, only lighter in proportion to the wooden work, we think a repetition needleſs.

REMARKS.

The wheels of the limbers being but four feet high, and the extremities of the ſhafts five, the draught of the ſhaft horſe becomes ſo oblique, that the greateſt part of his force is loſt in ſupporting the fore ends of the ſhafts, which the other horſes draw down again, ſo as to bring the whole draught in a right line from the axle-tree to the breaſt of the fore horſe; whereby the ſhaft horſe is ſo ſhook (the difference between the height of the fore end of the ſhafts and the center of the axle-tree being at leaſt two feet) that he is ſpoiled in a ſhort time, and rendered unfit for ſervice: on the other hand, the bolſter of a 24 pounder limber is 14 inches high from the center line of the axle-tree; when the carriage is moving, it endeavours to turn the limber about its axis, and the trail would ſlip out of the pintle, were it not for the limber chain that retains it. All theſe oblique motions being conſidered, it will be found by thoſe converſant in mechanic principles, that worſe cannot be contrived. It is very difficult to contrive better: for the trails of field carriages cannot be altered; and if the wheels were made higher and the bolſter lower, the carriage cannot turn ſo well in a narrow road, nor can the trail be fixed under the axle-tree for the ſame reaſon: the only remedy that can be found, in my opinion, would be to fix a pole or ſhafts in ſome way or other to the head of the carriage, ſo as to draw it forwards, and the trail to ſlide on the ground like a ſledge; but how this may be done muſt be left to ſome ingenious workman.

PART


XIV
A Coehorn Bed
A 10 Inch Land Mortar Bed
a
b
c
g
h
q
d
p
k
m
l
5
10
20
30
40 Inches

PART V.

Of mortar beds and howitz carriages.

THE land mortar beds are here made of ſolid timber, conſiſting generally of four pieces; thoſe of the royal and coehorns excepted, which are but one ſingle block. As to ſea mortars, their beds are made quite different from theſe, as will be ſhewn each in their order.

Dimenſions of land mortar beds. Plate XIV.

Bore,	13	10	8	5.8	4.6
	Inches				
Lower bed length,	84	66	50	0	0
Lower bed breadth,	33	20	0	0	0
Lower bed height,	13	10	9	0	0
Upper bed length,	83	65	49	31.5	28.5
Upper bed breadth,	32	25	19	16	14
Upper bed height,	13	12	11	10	9
Breadth quarter round,	3	2.5	2.5	0	0
Of the ogee and fillet,	4	3.5	3	0	0
Length of the cavity,	20	16	12	8	5.7
Trun. hole from fore end,	31	20	15.5	13.3	11.7
Diam. of trun. holes,	7.2	6.4	5.4	3.4	2.4
Depth of trun. holes,	7	6	5	3.2	2.2

The diſtance of the trunion holes is meaſured from the quarter round, and not from the end of the bed. The joint of the two pieces of the upper bed, in the 13, 10, and 8 inch beds, are ſo contrived as not to be directly over the joint of the pieces in the under bed.

Names and number of irons in a 13, 10, and 8 inch bed.

a. Cap ſquares, — — —	2
b. Eye bolts, — — —	2
c. Joint bolts, — — —	2
d. Under and upper bed bolts, — —	9
f. Dowel bars, — — —	4
g. Rings with bolts, — — —	4
h. Reverſe bar, — — —	2
k. End rivetting plates, — —	2
l. Middle plate, — — —	1
m. Rivetting bolts, — — —	6
n. Square rivetting plates, — —	12
p. Traverſing bolts, — — —	6
q. Keys, chains, and ſtaples, — —	2

Names and number of irons in a royal and coehorn bed.

a. Cap ſquares, — — —	2
b. Eye bolts, — — —	2
c. Joint bolts, — — —	2
d. Rivetting bolt with ring, — —	1
f. Handles with ſtarts, — — —	2
g. Square rivetting plates, — —	5
h. Keys, chains with ſtaples, — —	2

Dimenſions

Dimensions of beds for the three new mortars.

Diameter of the bore, —	30	30	30
Lower bed { length, —	6 : 0	5 : 10	4 : 25
Lower bed { breadth, —	2 : 10	2 : 2	1 : 26
Lower bed { thickneſs, —	0 : 28	0 : 25	0 : 22.5
Upper bed { length, —	5 : 28	5 : 8	4 : 23
Upper bed { breadth, —	2 : 8	2 : 0	1 : 24
Upper bed { thickneſs, —	0 : 28	0 : 25	[illegible] : 22.5
Breadth of the ogee, —	0 : 6	0 : 5	0 : 4.5
Of quar. round and fillet,	0 : 6	0 : 5	0 : 4.5
Diam. } of trun. holes	0 : 14	0 : 13	0 : 12
Depth } of trun. holes	0 : 10	0 : 9.5	0 : 9
Interval between them,	1 : 5	1 : 5	1 : 4
Their length, —	0 : 15	0 : 14	0 : 13

The firſt numbers in each column expreſs the diameters of the bore, and the ſecond the parts of that diameter divided into 30, as in the conſtruction of mortars. The center line of the trunion hole paſſes through the middle of the upper bed.

The dimenſions of the firſt of theſe beds will hold nearly true in regard to the preſent mortars. As to thoſe uſed at preſent, there is no proportion between them; ſome are larger and others ſmaller than they ſhould be; for it has been obſerved, that when the royal and coehorn are fired, their beds kick about very much, which is a certain ſign that they are too ſmall. We have obſerved before, that the mortars both here and in *France* are not conſtructed by any rule; the ſame is true in regard to their beds; and it is no wonder, ſince *St. Remy*, the only author who has wrote a compleat treatiſe upon artillery, did no more than copy ſuch memoirs as he received from the workmen, without pretending to reaſon upon the ſubject, and in all appearance was not qualified for it.

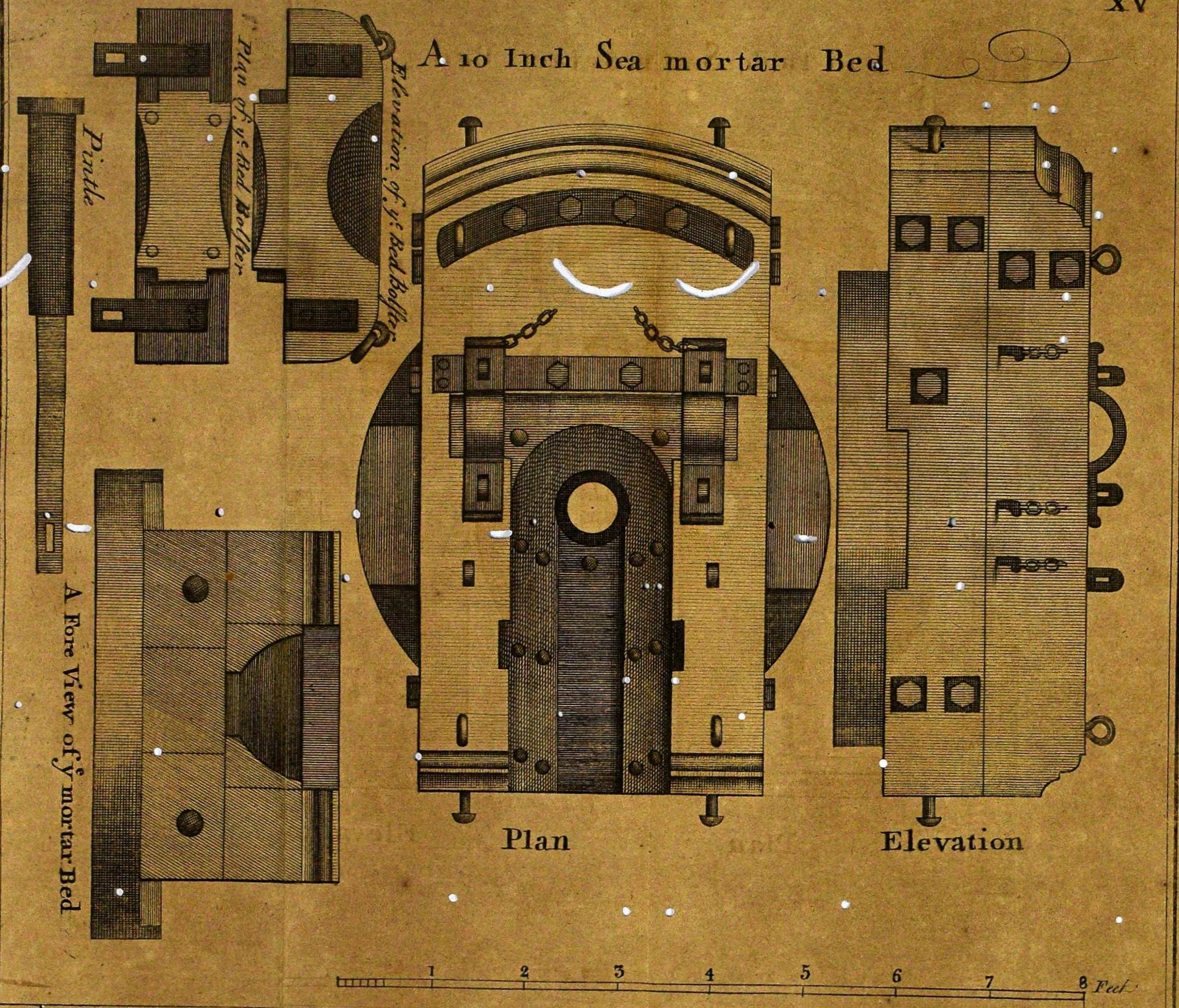
General

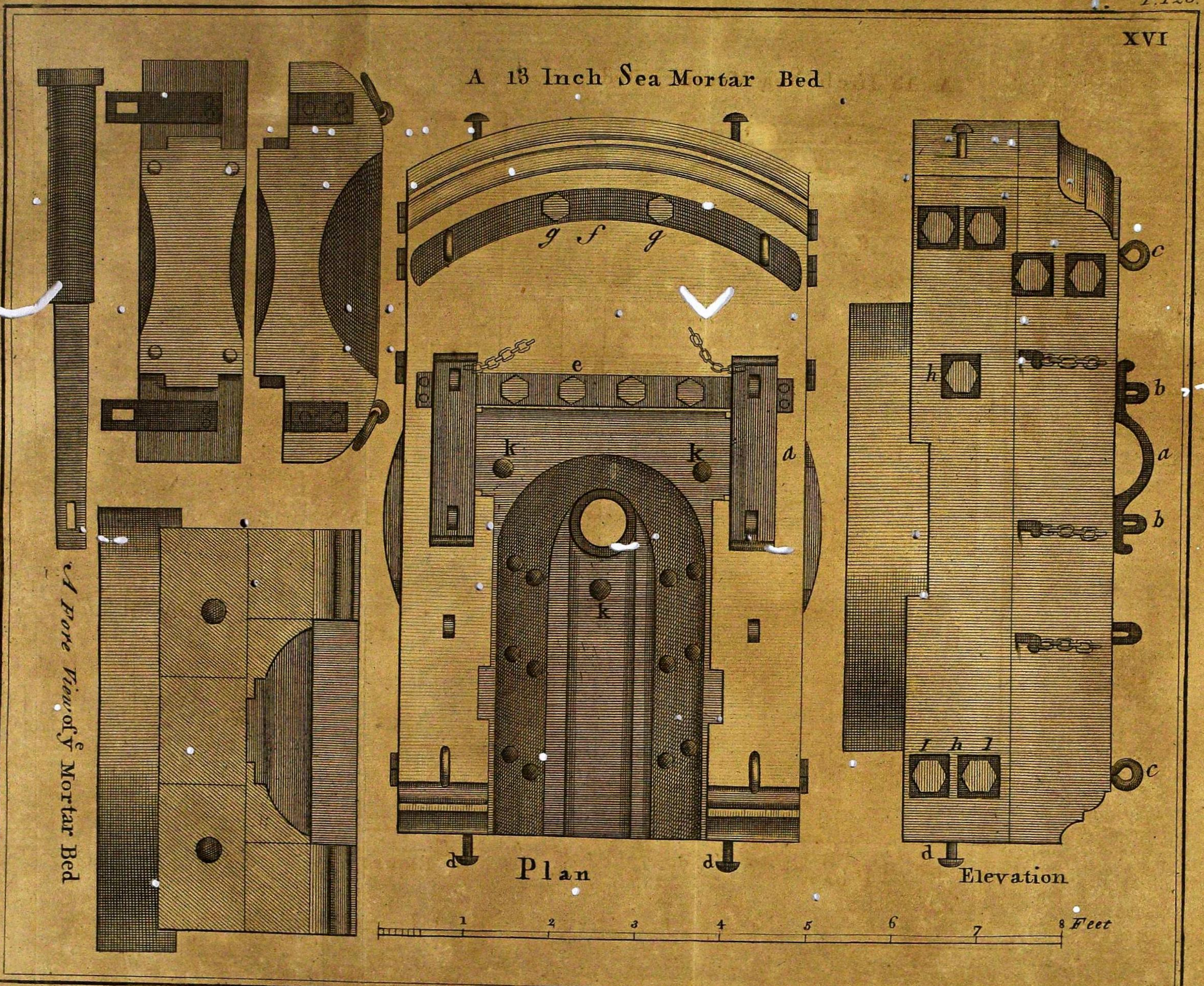
General dimenſions of the iron work.

Cap ſquare length, —	1 : 18	1 : 14	1 : 9
Cap ſquare breadth, —	0 : 12	0 : 10	0 : 8
Cap ſquare thickneſs, —	0 : 3	0 : 2. 5	0 : 2
Fore end from the trunion hole, — —	0 : 16	0 : 14	0 : 13
Eye bolt head height, —	0 : 8	0 : 7	0 : 6
Eye bolt head breadth,	0 : 7	0 : 6	0 : 5
Eye bolt head thickneſs,	0 : 3. 5	0 : 3. 5	0 : 3
Joint bolts head diameter, —	0 : 11	0 : 8. 5	0 : 7. 5
Joint bolts head thickneſs, —	0 : 3. 5	0 : 3. 5	0 : 3
Diſt. from the trun. hole,	0 : 10. 5	0 : 9. 5	0 : 7. 5
Traverſing bolt length, —	0 : 23	0 : 20	0 : 16
Diameter of head, —	0 : 4. 5	0 : 3. 5	0 : 3
Diameter of bolt, —	0 : 3	0 : 2	0 : 2
Their diſtanc from below, —	0 : 12	0 : 11	0 : 10
Their diſtanc from end —	1 : 2	0 : 29	0 : 24
Mid. plate length, —	2 : 8	2 : 0	1 : 24
Mid. plate breadth, —	0 : 9	0 : 7	0 : 6
Mid. plate thickneſs, —	0 : 1. 6	0 : 1. 5	0 : 1. 5
Bed bolt diameter, —	0 : 3	0 : 2. 5	0 : 2
Bed bolt length, —	2 : 10	2 : 2	1 : 26
Ring diameter, —	0 : 14	0 : 12	0 : 10
Ring thickneſs, —	0 : 3	0 : 2. 5	0 : 2
Diameter of the rivetting bolts, — —	0 : 3	0 : 2. 5	0 : 2
Diameter of the ring rivetting bolts, —	0 : 3	0 : 2. 5	0 : 2
Diſtance from the ends of the plates, — —	0 : 6	0 : 5	0 : 4
Dia. of the bed bolts burs	0 : 6	0 : 5	0 : 4
Rivetting plates length, —	1 : 27	1 : 19	1 : 14
Rivetting plates breadth, —	0 : 8	0 : 6	0 : 5
Rivetting plates thickneſs, —	0 : 1	0 : 1	0 : 1
From the quarter round,	0 : 8	0 : 6	0 : 5
Diameter of the traverſing bolt plates, —	0 : 11	0 : 10	0 : 10

We

A 10 Inch Sea mortar Bed




A 13 Inch Sea Mortar Bed
g f g
e
k k
a
k
d
Plan
d
c
h
b
a
b
c
f h f
d
Elevation
A Fore View of ye Mortar Bed
1
2
3
4
5
6
7
8 Feet

We ſuppoſe theſe mortars ſo fixed in their beds as to be moveable, quite contrary to the preſent practice, and that they may be raiſed from an angle of 10 degrees to any under 90; for which reaſon the depth of the trunnion hole is not equal to its diameter, and the cavity in the bed is to be made in ſuch a manner as to receive the wedges by which the mortar is raiſed.

Dimenſions of ſea mortar beds. Plate XV, XVI.

Diameter of the bore,	13	10
Length of the bed,	94	84
Breadth of the bed,	54	47
Height of the bed,	27	23
Pintle hole from the fore end,	39	32
Diameter of the pintle hole	6.5	6.5
Trunions from the fore end,	46	42.5
Diameter of the trunion holes,	10	8
Depth of the trunion holes,	8	5
Diameter of the circular bed,	59	59
Height of the circular bed,	8	6
Diſtance to the bed bolſter,	15	16
Depth of the cavity,	15	12
Its opening above,	30	21
Bed bolſter length,	53	44
Length below,	29	2.1
Its height,	16	17
Its breadth,	14	12

Theſe beds are placed upon very ſtrong timber frames, fixed into the bomb ketch, to which the pintle is fixed ſo as the bed may turn about it. The fore part of theſe beds is an arc of a circle deſcribed from the ſame center as the pintle hole. The plans, elevations, and different ſections ſhew in a diſtinct manner the ſeveral parts of theſe beds.

Iron.

Iron work of these beds.

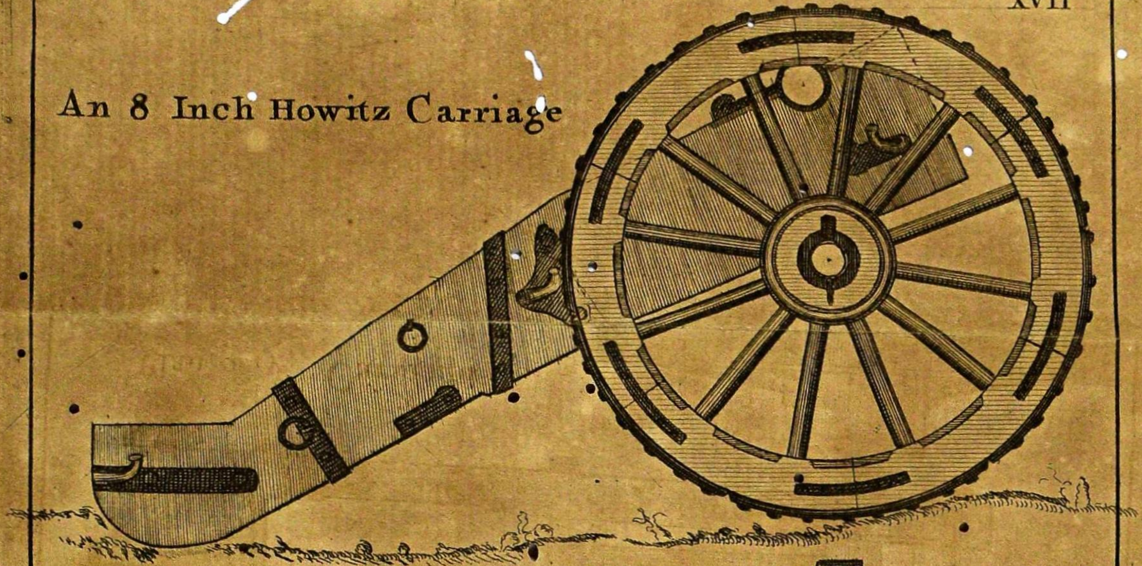
a. Cap squares,	2
b. Eye bolts,	6
c. Loop bolts,	4
d. Traversing bolts,	4
e. Middle plate,	1
f. Riveting plates,	1
g. Riveting bolts,	6
h. Cross bed bolts,	7
l, Square riveting plates for ditto,	7
k. Down bed bolts,	15
m. Bed bolster plates,	2
Keys, chains and staples,	6
Nails to the bed bolster bed,	4
Bed bolster rings with loops,	2

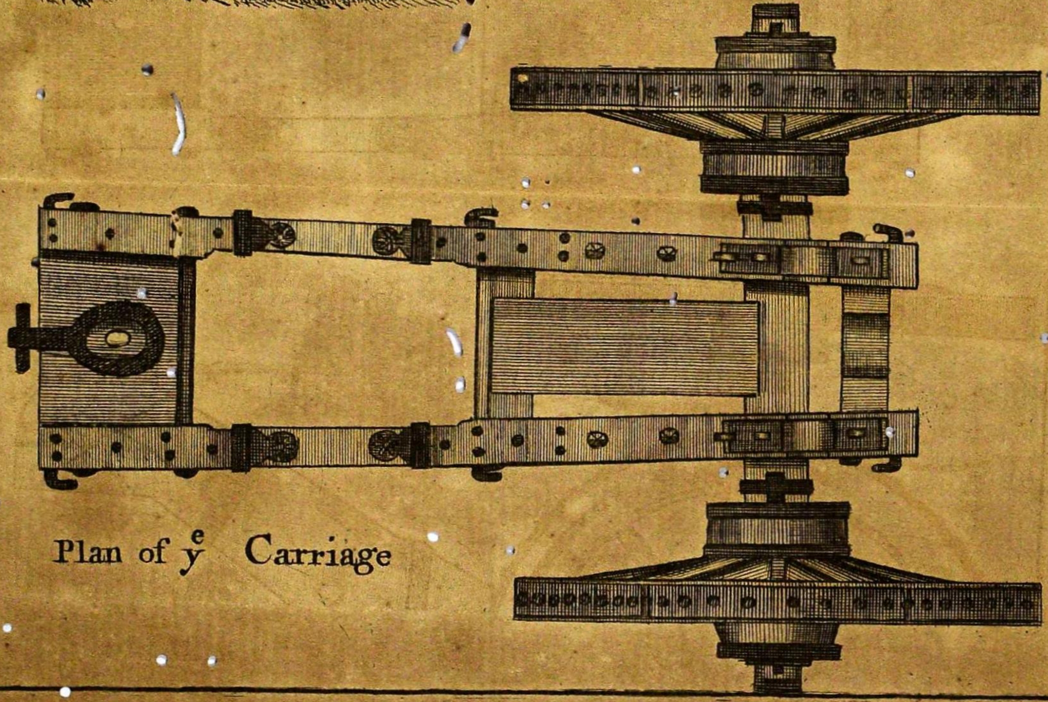
Dimensions of an eight inch howitz carriage. Plate XVII.

Length of the cheeks,		101
Thickness,		4. 5
Height before,		18
Height at the	center,	16
	trail,	14
Length of the trail,		15
Height of the plank,		18
From the head to the center,		43
Trunion holes from the head,		9
Breast transom	length,	14. 5
	height,	
	thickness,	4. 5
Center transom	length,	16. 5
	height,	
	thickness,	4. 5
Trail transom	length,	19
	breadth,	15
	thickness,	

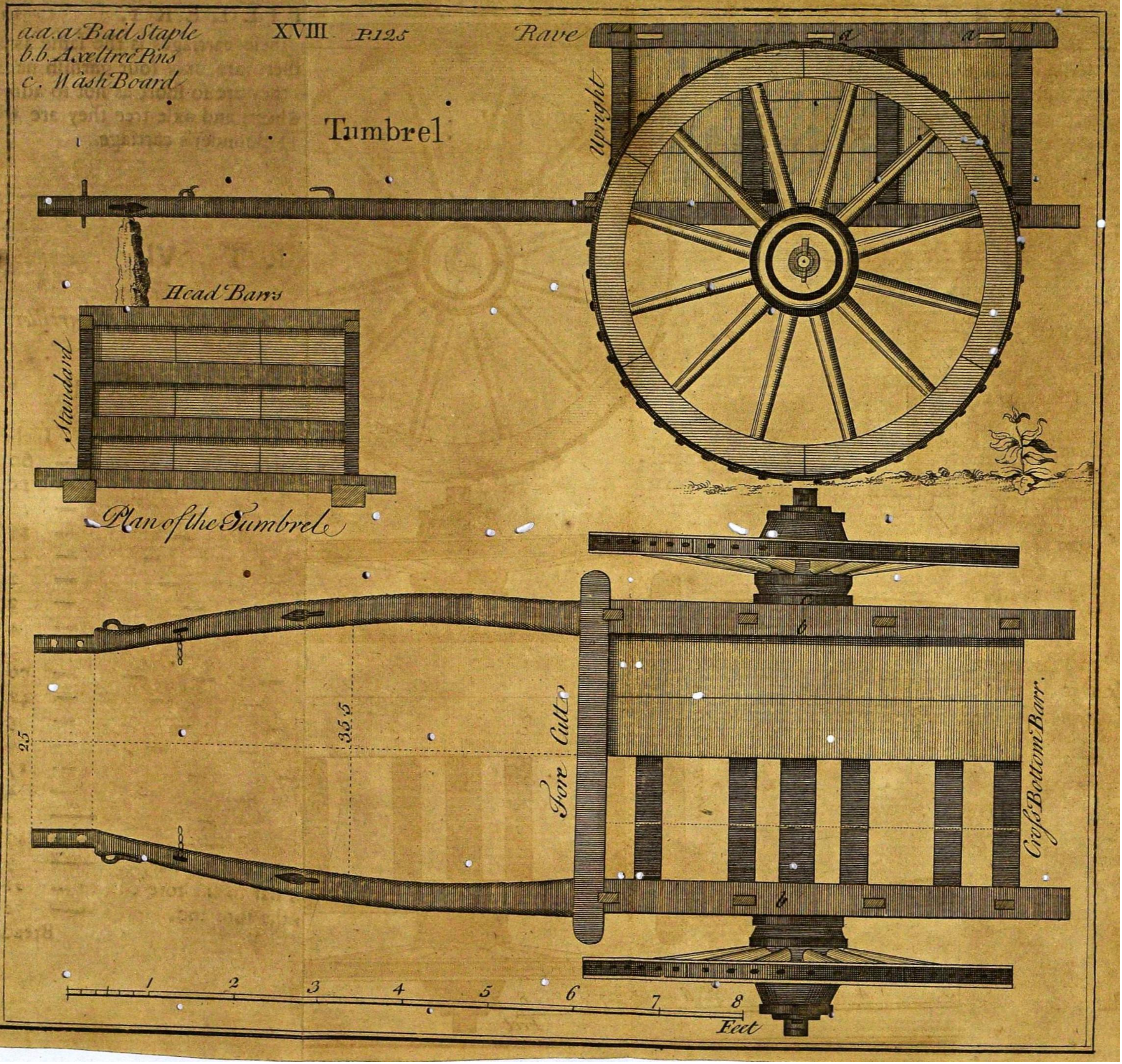
The

An 8 Inch Howitz Carriage





Plan of y^{e} Carriage



a.a.a. Bail Staple
b.b. Axeltree Pins
c. Wash Board
XVIII P.125
Rave
Upright
Tumbrel
Head Barrs
Standard
Plan of the Tumbrel
Fore Cutt
Cross Bottom Barr.
25
35.5
1 2 3 4 5 6 7 8
Feet

The iron work of these carriages is the same as in field carriages; but there are only four garnish nails, two of a side, because they are so short as not to admit of more. As to the wheels and axle-tree they are the same as in an 18 and 12 pounder's carriage.

PART VI.

Of different sorts of carriages used in the artillery.

Dimensions of a Tumbrel. Plate XVIII.

		Inches.
DIAMETER of the wheel,		60
Nave length,		15
Diameters	body,	12
	middle,	13
	linch,	10
Spokes	breadth,	2.2
	thickness,	3.3
Fellows	breadth,	4.5
	thickness,	3.5
Axle-tree length,		76
Body	length,	42
	breadth,	5
	height,	6.7
Arms length,		17
Diameters	body,	4.5
	linch,	3
Shafts total length,		147
From the hind	end to the cross bar,	7
	cross bar to the fore cut,	62
From the fore cut to the fore end,		78

Breadth,

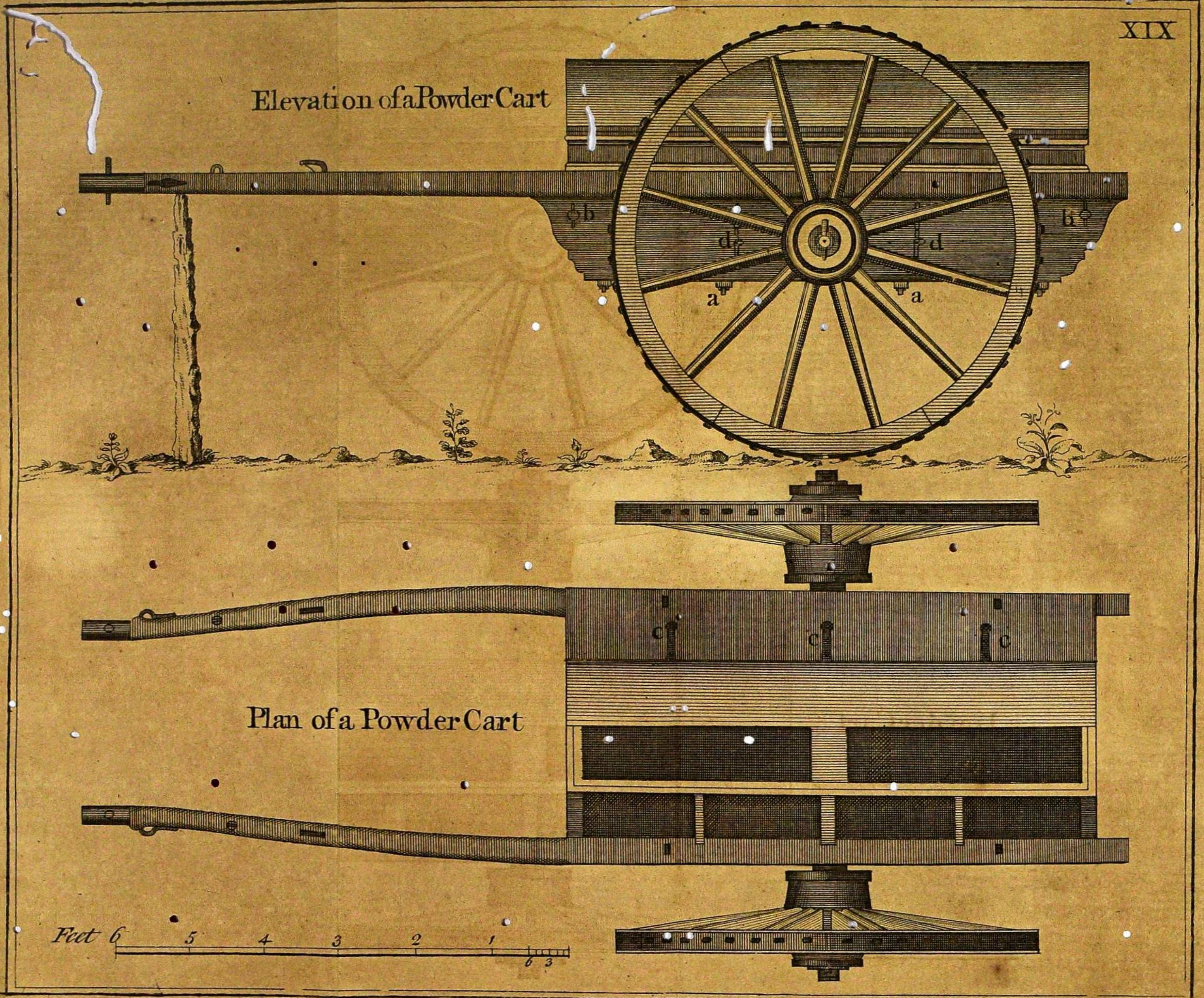
		Inches.
Breadth	behind	4
	at the fore cut	4. 5
	in the middle	3. 5
	at the fore end	2. 3
Height from the hind end to the fore cut		3. 5
Height at the fore end		2. 3
Width within	behind and at the fore cut	34
	in the middle	35
	at the fore end	25
Crofs bars	breadth	3. 5
	thicknefs	2
	length	31
Fore cut	length	51
	breadth	4
	thicknefs	2
Raves	length	62
	breadth	2
	thicknefs	3
Standards	length	24
	breadth	2. 8
	thicknefs	1. 3
Head bars	length	36
	breadth	1. 2
	thicknefs	1. 8
Uprights	length	22
	breadth	1. 3
	thicknefs	3

Iron work of a tumbrel.

A pair of wheels and axle-tree compleat.	
Axle-tree pins with rings and keys	2
Fore cut pins	2
Breech hooks	2
Shaft rings	2
Shaft pins with chains and ftaples	2
Ridge chain with hook and loop	1
Bail ftaples	6

The

XIX


Elevation of a Powder Cart
b
b
d
d
a
a
c
c
c
Plan of a Powder Cart
Feet 6
5
4
3
2
1
6
3

The common uſe of tumbrels is to carry the pioneers and miners tools; but they ſerve likewiſe to carry the money of the army.

Dimenſions of a powder cart. Plate XIX.

The wheels and axle-tree are the ſame as in the tumbrel, except the height of the wheels is here 5.5 feet.

		Inches
Sides with ſhafts, total length		180
From the hind	end to the croſs bar	5.5
	croſs bar to the fore croſs bar	88.5
From the fore croſs bar to the fore end		77.5
Breadth	behind	3.3
	fore croſs bar	4.4
	middle	3.7
	before	2.8
Height	behind	3
	fore croſs bar	4
	before	2.8
Opening behind, and at the fore croſs bar		34
At	middle	35
	before	25
Two ſhaft croſs bars	length	34
	breadth	2
	height	3
Under croſs bars	length	40
	breadth	3
	height	2
Side pieces	length	100
	breadth	13
	height	3
The axle-tree paſſes through the ſide pieces from the bottom		3
From the ſhafts to the beginning of the roof		6
Height of the roof		12
Lids	length	88
	breadth	10
	thickneſs	1

Roof

		Inches.
Roof lids	length	88
	breadth	11
	thickneſs	1

The roof is covered with oil cloth to prevent dampneſs from coming to the powder, and each ſhot locker is divided into four parts by boards of an inch thick, which enter about an inch into the ſhafts. Each of theſe carts can ſtow four barrels of powder only.

Iron work of a powder cart.

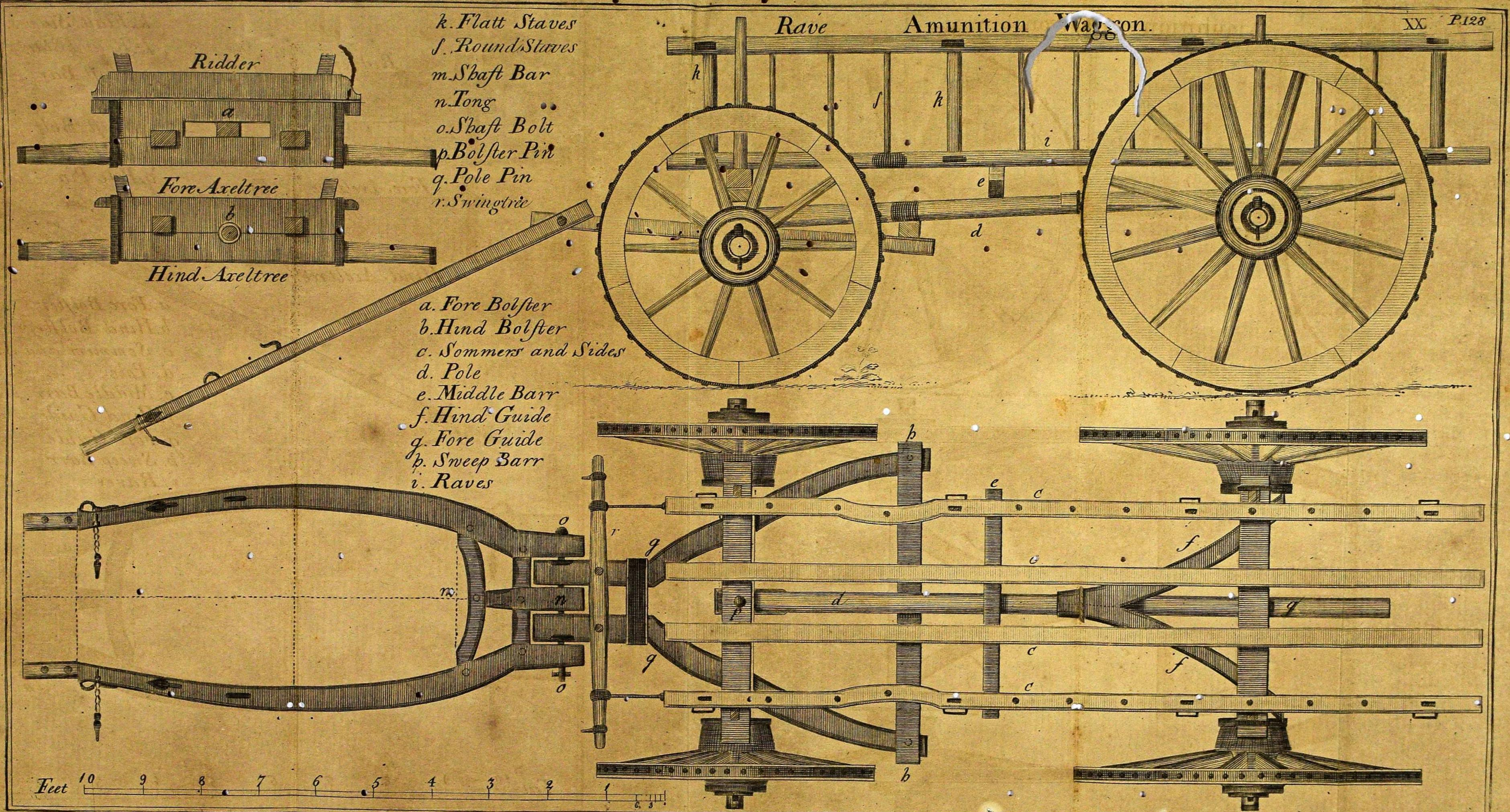
a. Side bolts with ſcrews	8
b. Croſs bolts with ſingle keys	2
c. Double hinges for the ſhot lids	6
d. Staples and keys with chains	4
e. Hinges for roof lids	2
f. Haſps, ſtaples, and keys for ditto	3
g. Axle-tree pins with keys	2

Compleat irons for ſhafts, wheels, and axle-tree.

Dimenſions of an ammunition waggon. Plate XX.

		Inches.
Fore wheels, height		48
Nave, length		13
Diameter	body	12
	middle	14
	linch	10
Fellows	breadth	3
	height	4
Spokes	breadth	1.5
	thickneſs	3
Hind wheels, height		60
Nave, length		13
Diameters	body	12
	middle	14
	linch	10

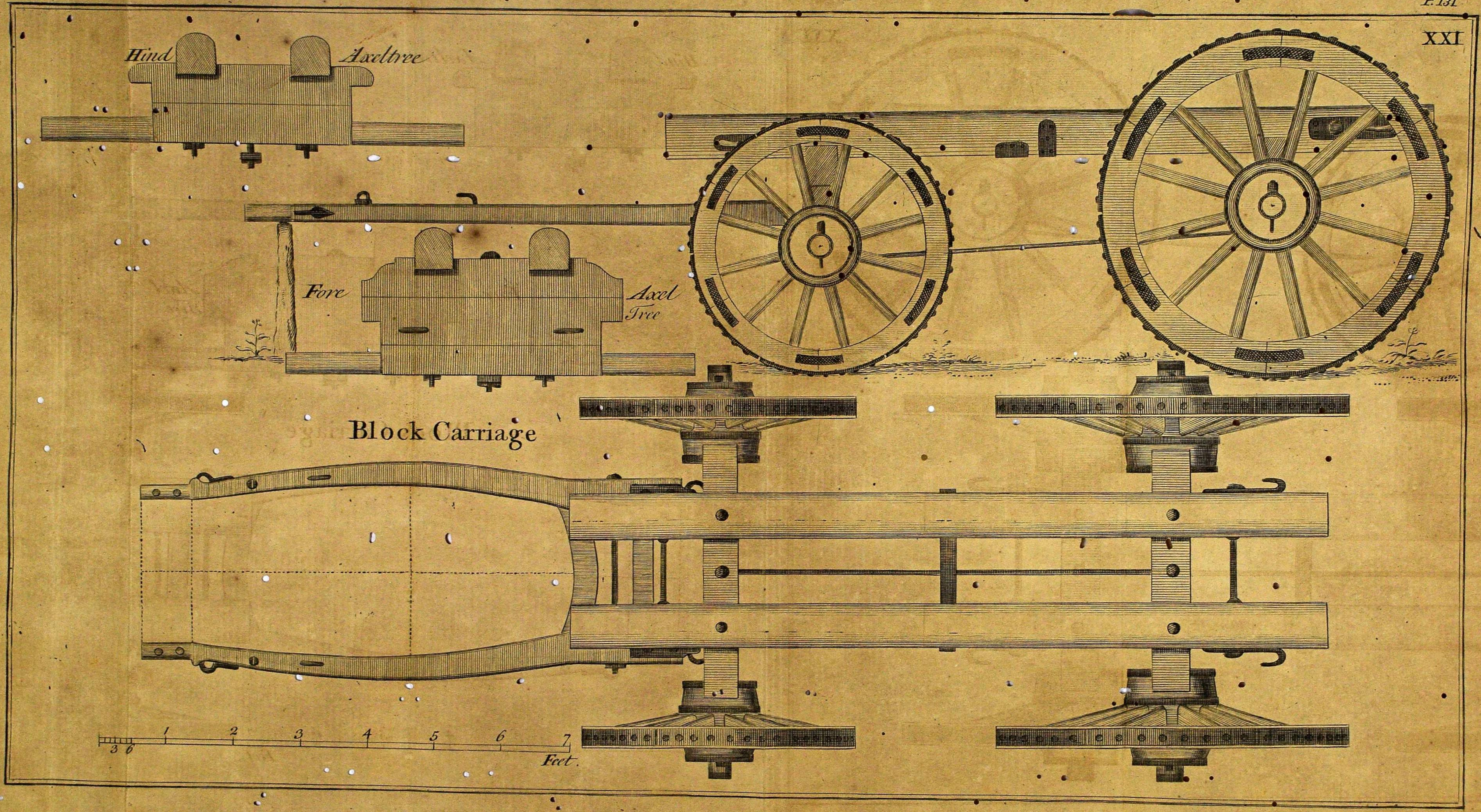
Fellows


XX P.128
Amunition Waggon
Rave
Ridder
Fore Axeltree
Hind Axeltree
k. Flatt Staves
ſ. Round Staves
m. Shaft Bar
n. Tong
o. Shaft Bolt
p. Bolster Pin
q. Pole Pin
r. Swingtree
a. Fore Bolster
b. Hind Bolster
c. Sommers and Sides
d. Pole
e. Middle Barr
f. Hind Guide
g. Fore Guide
h. Sweep Barr
i. Raves
Feet 10 9 8 7 6 5 4 3 2 1

		Inches.
Fellows	breadth	3
	height	4
Spokes	breadth	1.8
	thickneſs	3.5
Fore axle-tree, total length		72
Body	length	40
	breadth	5
	height	6
Arms, length		16
Diameters	body	5
	linch	3
Hind axle-tree, total length		70
Body	length	38
	breadth	5
	height	6
Arms, length		16
Diameters	body	5
	linch	3
Fore bolſter	length	49
	breadth	5
	height	6
Hind bolſter	length	46
	breadth	5
	height	6
Rider	length	49
	breadth	5
	height	4.7
Sommers and ſides	length	144
	breadth	3
	height	3
Pole	length	120
	ſquare before	4
	ſquare behind	3
Middle bar	length	40
	breadth	3.5
	height	6.5

		Inches.
Hind guide	length to the axle-tree	28
	breadth at the head	5
	ſquare at the axle-tree	3
	opening at the axle-tree	24
Fore guide	length to the axle-tree	32. 5
	breadth before	5
	breadth behind	4
	thickneſs	3
Length of the ſtraight part		20
Length from the axle-tree to the hind end		28
Opening	to receive the tong	4
	near the axle-tree	19
	behind	40
Sweep bar	length	50
	breadth	3. 5
	height	2. 5
Raves	length	144
	breadth	2. 2
	height	2. 2
Flate ſtaves	length	15. 5
	breadth	2. 5
	thickneſs	1
Shafts length		67
Length of the ſtraight part		10
Breadth	behind	3. 2
	at the fore ſhaft bar	5
	before	3
Thickneſs before		3
Opening	at the ſhaft bolt	15
	at the fore ſhaft bar	21
	in the middle	30. 5
	before	24
Shaft bars	breadth	3
	thickneſs	2
Tong	length	17
	breadth	3. 6
	thickneſs	3

Length


Hind
Axeltree
Fore
Axel
Tree
Block Carriage
1
2
3
4
5
6
7
3 6
Feet.

	Inches.
Length of the guide bar — —	50
Breadth { in the middle — —	3
Breadth { at the end — — —	1.5
Thickneſs — — —	1.5
Diſtance from the center of one axle-tree to the other — — —	89

The ſommers go 10 inches beyond the fore axle-tree, and 38 beyond the hind.

Iron work of an ammunition waggon.

Pintle — — — —	1
Pole pin — — —	1
Bolſter pins with keys — — —	4
Locking plates — — —	2
Bail ſtaples — — —	16
Sweep bar pins — — —	2
Shaft bolt with key — —	1
Swing tree pins — — —	2
Hooks for ditto — — —	2
Bars to fix the ſwing-tree to the axle-tree —	2
Plate for the croſs bar of the fore guide —	1
Waſhing plates for the ſhafts — —	2
Bolſter bands — — —	4
Pole plate — — — —	1

Irons compleat for ſhafts, axle-trees, wheels, dowledges excepted.

This waggon ſerves likewiſe to carry bread, it being lined round in the inſide with baſket work.

Dimenſions of a block carriage. Plate XXI.

	Inches.
Fore wheels, height — —	48
Nave length, — — —	15
Diameters { body — —	14
Diameters { middle — — —	15
Diameters { linch — — —	13

		Inches.
Fellows	height	5. 5
	breadth	3. 5
Spokes	breadth	2
	thicknefs	3
Hind wheels, height		60
Nave, length		17
Diameters	body	14
	middle	15
	linch	13
Fellows	height,	6. 5
	breadth,	4
Spokes	breadth,	2. 3
	thicknefs,	4
Fore axle-tree, total length		77
Body	length	39
	breadth	6. 5
	height	8
Arms, length		19
Diameters	body	6
	linch	4
Bolfter	length	49
	breadth	6. 5
	height	7
Hind axle-tree, total length		77
Body	length	37
	breadth	7
	height	8. 7
Arms, length		20
Diameter	body	6
	linch	4. 8
Bolfter	length	47
	breadth	7
	height	8
Side pieces	length	132
	breadth	6. 5
	height	6. 5
Diftance between the axle-trees		72

The

		Inches.
The ſide pieces project equally by		24
Shafts, length		96
Breadth	behind	5.3
	in the middle	6
	before	3
Length of the ſtraight bar		19
Opening	behind	28.5
	middle	32.5
	before	24
Height of the ſhafts		3
Rider	length	46
	breadth	6.5
	height	8
Interval between the ſide pieces		12
The ſide pieces are let into the rider and hind bolſter		2

Iron work of a block carriage.

Irons compleat for wheels, axle-tree, and ſhafts.

1 Iron bar to faſten the hind axle-tree to the fore one.

2 Bolts to fix this bar to the axle-trees.

4 Bolſter bolts.

4 Hooks faſtened to the ſide pieces with two bolts and burs.

1 Bar to faſten the ſide pieces in the middle.

2 Staples for ſhafts, and two iron bands with loops.

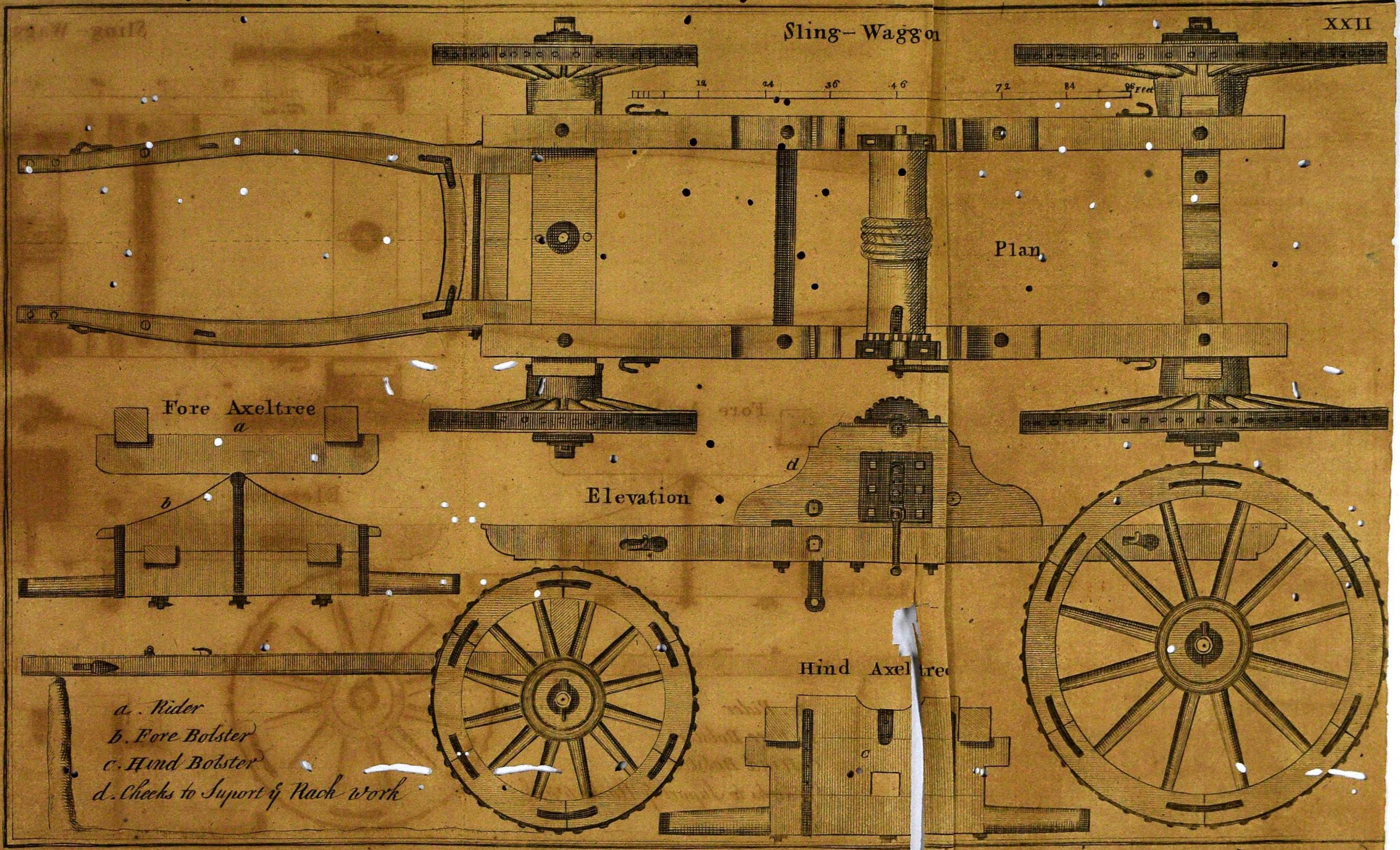
2 Loops, one faſtened to the rider, and the other to [th]e hind bolſter.

The uſe of this carriage is to carry guns in the field, [wh]ich are too heavy to be tranſported upon their own [car]riages, as likewiſe mortars and their beds.

Dimensions of a sling waggon. Plate XXII.

		Inches.
Side pieces	length	152
	breadth	6
	height	7. 8
	opening	32
	exceed, axle-tree	10
Interval between the centers of the axle-trees		123
Fore wheel, height		48
Nave, length		14
Diameters	body	13
	middle	14
	linch	11
Fellows	breadth	3. 8
	height	55
Spokes	breadth	2, 2
	thickness	3. 5
Hind wheel height		68
Nave, length		17
Diameter	body	16
	middle	17
	linch	13
Fellows	breadth	4. 4
	height	6
Spokes	breadth	2. 2
	thickness	4
Fore axle-tree, length		75. 5
Body	length	41. 5
	breadth	5
	height	8
Arms, length		17
Diameter	body	5
	linch	3
Hind axle-tree, length		81
Body	length	41
	breadth	5
	height	7

Arms,



Sling-Waggon
12
24
36
46
72
84
96 Feet
Plan
Fore Axeltree
a
b
Elevation
d
Hind Axeltree
c
a. Rider
b. Fore Bolster
c. Hind Bolster
d. Cheeks to Suport y^e Rack work

		Inches.
Arms, length		20
Diameter	body	5
	linch	4
Fore bolster	length	41. 5
	breadth	5
	height	12
Hind bolster	length	51
	breadth	5
	height	11
Rider	length	54
	breadth	5
	height	7. 2
Cheeks to support the rack work	length below	60
	length above	22
	height	20
	breadth	6
Shafts, length		94
Breadth	behind	5. 5
	middle	4
	before	3
Opening	behind	23
	middle	34
	before	25
Thickness of the shafts		3

Iron work of a sling waggon.

2 Cap squares.
4 Eye bolts.
2 Trunion plates.
2 Beam hooks.
1 Iron to fasten the tooth wheel.
Rack work with pland and handle.
An iron bar to stop the jack.
8 Bolts with screws to fasten the cheeks to the side pieces.
2 Hind axle-tree stays with bolts.

A croſs bar to faſten the ſide pieces together.

4 Hooks faſtened to the ſide pieces with bolts and burs.

4 Bolſter bolts with rings and keys.

Pintle with band and waſher.

4 Bolſter hoops.

Wheels and ſhafts compleat.

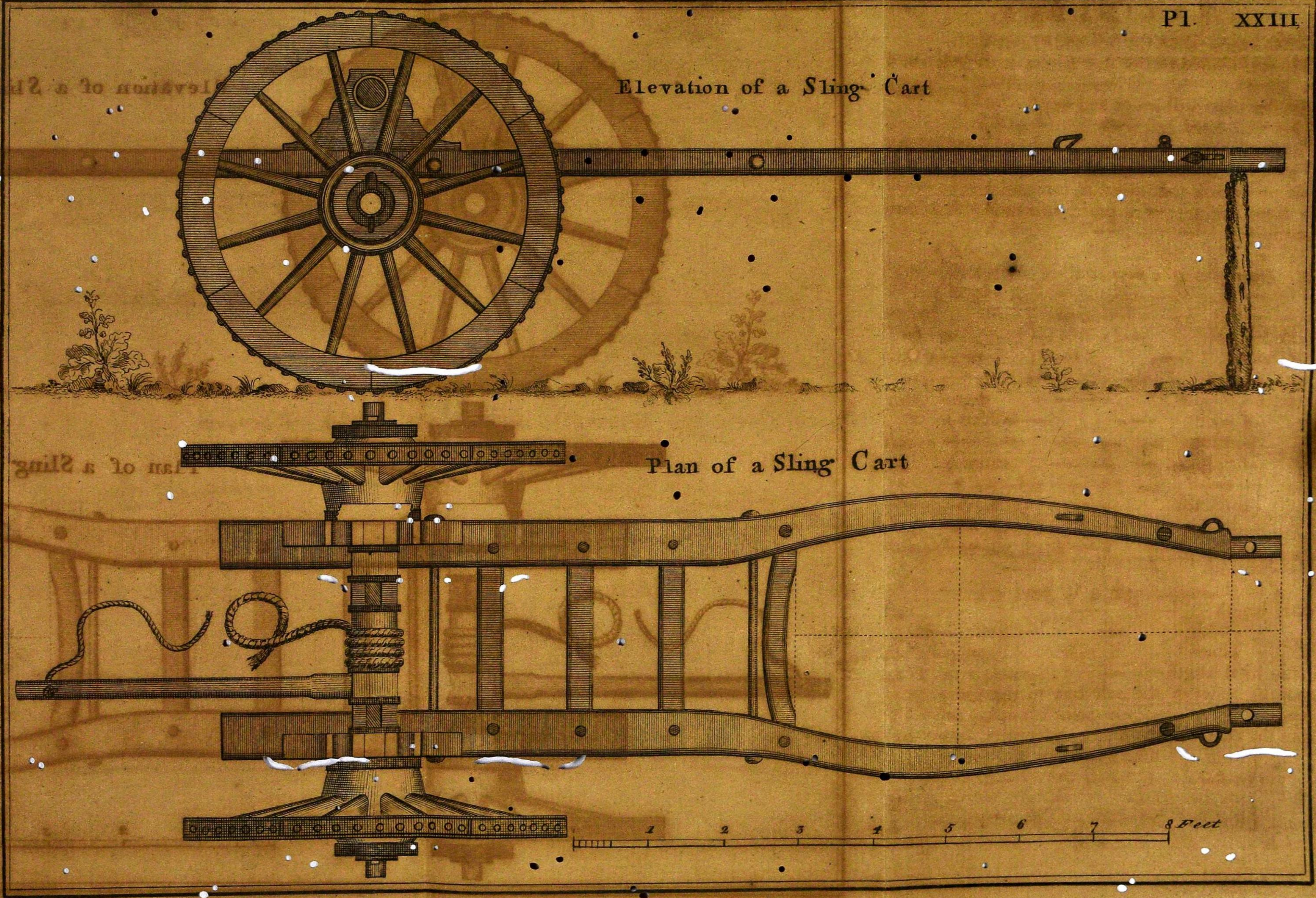
The uſe of this carriage is to carry mortars or heavy guns from one part of a place to another at a ſmall diſtance.

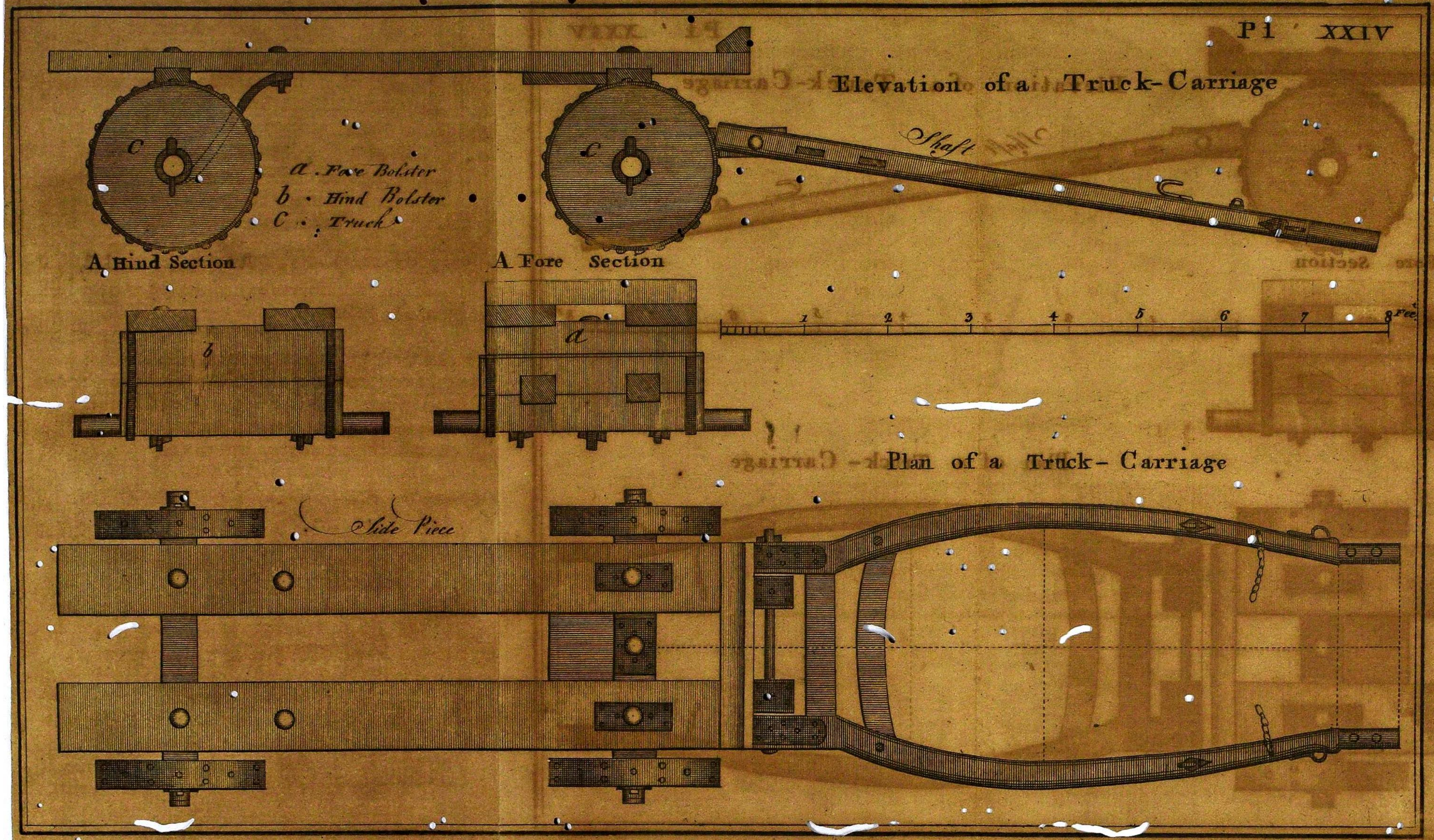
Dimenſions of a ſling cart. Plate XXIII.

		Inches.
Wheels height		60
Nave length		15.5
Diameter	body	14
	middle	16
	linch	12
Fellows	breadth	3.4
	height	5.5
Spokes	breadth	2
	thickneſs	3
Axle-tree, length		77.5
Body	length	40.5
	breadth	5
	height	5.5
Arms, length		18.5
Diameter	body	5
	linch	4
Shafts, total length		168
From the center of the axle-tree to the fore end		144
From the center to the hind end		24
Breadth	from the hind end to the fore croſs bar	7
	middle	5
	fore end	3.4

Opening

Pl. XXIII.




Pl XXIV
Elevation of a Truck-Carriage
Shaft
a . Fore Bolster
b . Hind Bolster
C . Truck
A Hind Section
A Fore Section
1 2 3 4 5 6 7 8 Feet
Plan of a Truck-Carriage
Side Piece

		Inches.
Opening	axle-tree and fore croſs bar	23
	middle	30
	before	24
Height of the ſhafts		3. 6
Croſs bars	breadth	4
	thickneſs	2
Cheeks to ſupport the roller	length below	28
	above	7
	height	9
	thickneſs	4
	interval	32
Diameter of the roller.		7

This cart ſerves for the ſame uſes as the former waggon, but chiefly to carry the guns from the water ſide to the proof place, and from thence back again.

The iron work of this cart is the ſame as before, as alſo of the wheels, axle-tree, and ſhafts.

Dimenſions of a truck carriage. Plate XXIV.

		Inches.
Fore axle-tree	body length	32
	breadth	5
	height	11
	arms length	6. 5
	diameter	3
Hind axle-tree	body length	32
	breadth	6
	height	7. 8
	arms length	6. 5
	diameter	3
Side pieces	length	100
	breadth	10
	height	2. 5
	interval	10
	to the fore axle-tree	15
	to the hind axle-tree	15

Fore

		Inches.
Fore bolster	length	32
	breadth	5
	height	6
Hind bolster	length	32
	breadth	6
	height	8
Shafts	length	96
	height	3.3
Opening	near the bolt	23
	middle	35
	before	24
Breadth	before	3
	middle	4
	at the bolt	3.5
From the end to the straight cross bar		12
Fore guide	length	30
	breadth	21
	height	4
	interval	10
Trucks	diameter	25
	thickness	4

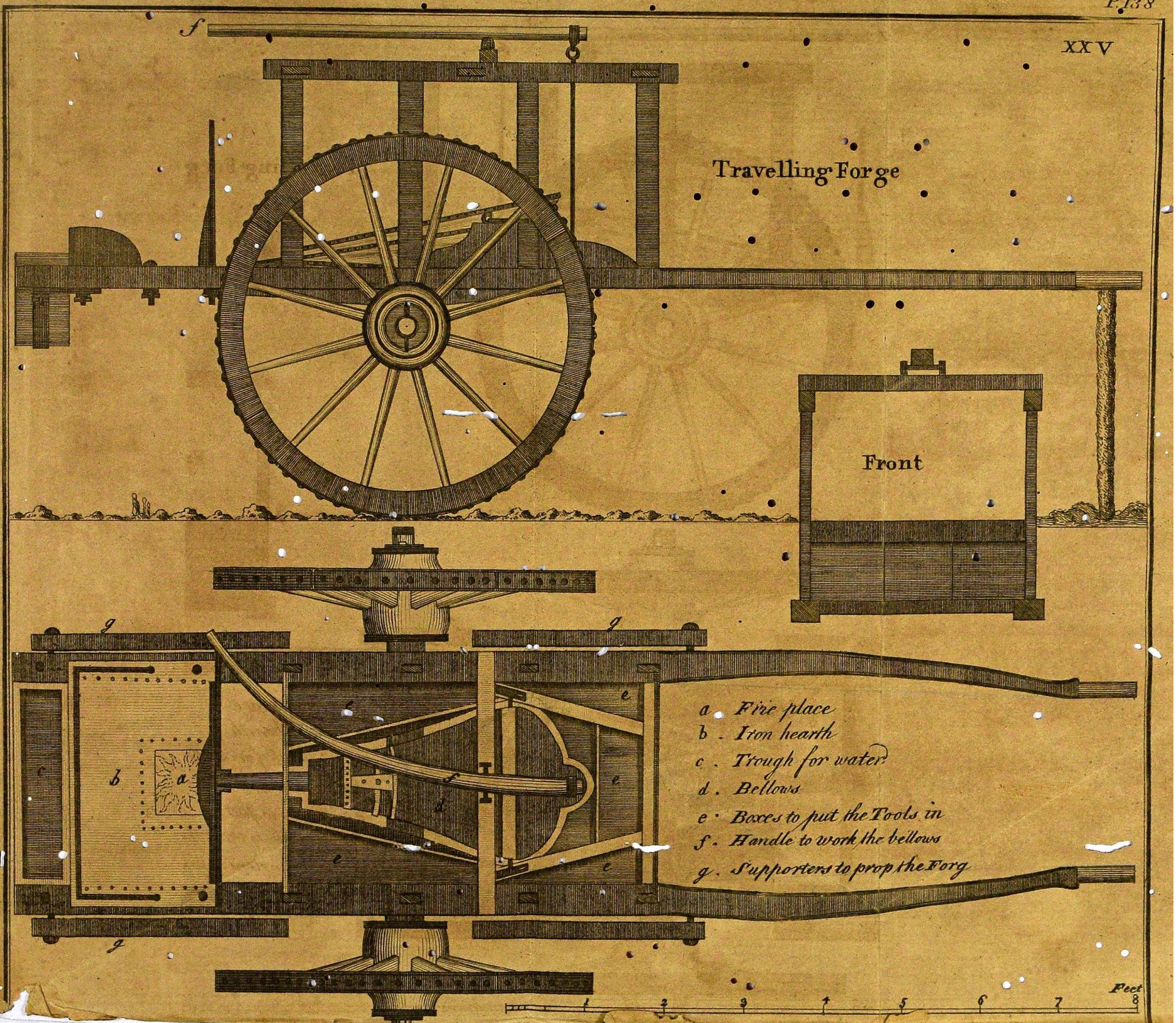
The cross piece fixed upon the fore ends of the side pieces is 5 inches broad, 3 high before, and 1.5 behind.

The cross piece behind the fore bolster under the side pieces is ten inches broad, and 1.5 thick. The bolsters are let into the side pieces about half an inch. The iron work is so distinctly seen in the plan and elevation of this carriage, that it would be needless to mention it.

The use of this carriage is to carry timber and other burthens from one place to another.

Dimensions of a travelling forge. Plate XXV.

	Inches.
Wheels, diameter	56
Nave, length	14
	Diameter


XXV
Travelling Forge
Front
f
g
a
b
c
d
e
a . Fire place
b . Iron hearth
c . Trough for water
d . Bellows
e . Boxes to put the Tools in
f . Handle to work the bellows
g . Supporters to prop the Forg
Feet
1
2
3
4
5
6
7
8

		Inches.
Diameters	body	12
	middle	13
	linch	9
Fellows	breadth	3
	height	4
Spokes	breadth	1.7
	thickneſs	3
Axle-tree length		76
Body	length	42
	breadth	5
	height	6
Arms, length		17
Diameters	body	5
	linch	3
Shafts with ſides, total length		167
Length of the ſhafts		72
Breadth	behind	4
	middle	4. 5
	before	2. 8
Height	behind	3
	middle	4
	before	2. 8
Opening	before	25
	middle	33
	axle tree	30
Raves	length	61
	breadth	3
	height	2. 2
Uprights	length	27
	breadth	3
	thickneſs	2. 2
Fore croſs bar	breadth	3
	thickneſs	2. 2
From the hind upright to the end		40
From the hind end to the axle-tree		55

EXPLANATION.

a. The bellows.
b. Place boarded up to put the tools in.
c. Iron plate for the fire place.
d. Wooden trough for water.
f. Iron plate to receive the cinders, and to lay the hammers and tongs upon.
g. Iron plate to prevent the flame ſetting fire to the carriage.

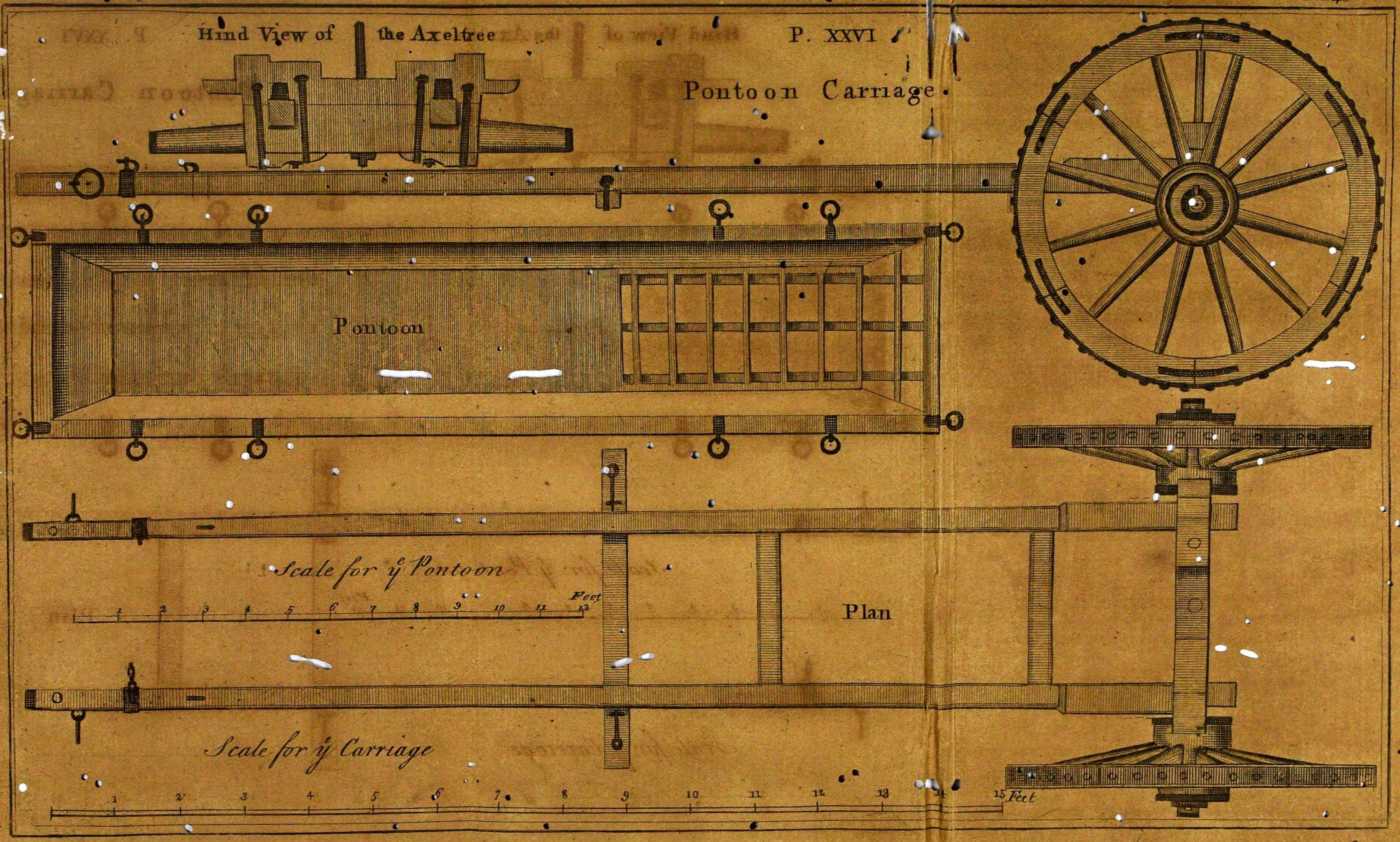
This forge is very ill contrived: it ſhould have four wheels, that it might ſtand firm, and be eaſier carried; the *French* uſe ſuch as this laſt deſcribed.

Since the firſt impreſſion of this work theſe forges have been made with four wheels: the ſame has ſince been done in regard to the pontoon carriage, where they now uſe limbers, which mend it in part, but not compleatly; for it ought to be a compleat four-wheel carriage, and not one with limbers.

Dimenſions of a pontoon carriage. Plate XXVI.

		Inches.
Wheels, diameter		68
Nave, length		15
Diameters	body	14
	middle	15
	linch	12
Fellows	breadth	4
	height	5 5
Spokes	breadth	2
	thickneſs	3. 5
Axle-tree, length		82
Body	length	46
	breadth	6
	height	8. 5
Arms, length		18

Diameter


Hind View of the Axeltree
P. XXVI
Pontoon Carriage
Pontoon
Scale for yͤ Pontoon
Feet
1 2 3 4 5 6 7 8 9 10 11 12
Plan
Scale for yͤ Carriage
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Feet

		Inches.
Diameter	body	6
	linch	3.5
Bolster	length	54
	breadth	6
	height	18
Side pieces with shafts length		228
Breadth	axle-tree	5
	middle	4
	before	3.2
Height	behind the axle-tree	4.8
	before the axle-tree	6
	at 21.5 from it	5.2
	at the end	3.2
Opening	near the axle-tree	29
	at the fore cross bar	28
	before	28
Fore cross bar	breadth	4
	height	3.5
	length	60
Distance from the shafts end		108
Next cross bar	breadth	4
	height	2.5
Distant from the first		24

The cross bar next to the axle-tree is of the same dimensions as the last, and 24 inches distant from the axle-tree.

The shafts slip through the axle-tree, and are pinned behind, so that they may be taken out when the carriage is to be put into the storehouse; for which reason they are made higher before, so as to afford a shoulder against the axle-tree.

Dimensions of a pontoon.

	Feet.	Inch.
Total length of the pontoon	21	0
Length of the bottom	16	8

Width

		Feet.	Inch.
Width above and below at the outside		4 :	10
Height of the sides	— —	2 :	5
Width within	above — —	3 :	11
	at the bottom —	3 :	5
Depth within	— —	2 :	1.5
Width of	three long bars underneath	0 :	3
	the two side ones underneath	0 :	3.8
Breadth of the	upper ones —	0 :	5.5
	cross bars — —	0 :	1.7
Distant from each other	— —	0 :	9
Length of the timbers laid across	—	22 :	8
Breadth and height of ditto	—	0 :	4

There are four of these timbers for each pontoon, and as they lay across over two pontoons, there are 5 placed at the side of each other, the planks laid over them are an inch and a quarter thick, and 11.5 feet long. There are likewise two long narrow boards laid on each side of the bridge over the ends of the cross ones, and fastened to them with wooden bolts, to keep the carriages from running off. The XXVIth plate shews the plan of the pontoon, one part of which is left open at the bottom, to shew the wooden work; both out and insides are covered with the strongest tin plates; the outside bottom is of the same breadth as the pontoon is at the top, the sides included, but the inside bottom is less broad, so that there is a hollow between the inside and outside, divided into apartments by the side pieces, in order that if a hole should be made in the outside by a shot or accident, the inside might not be filled, and the pontoon rendered less boyante.

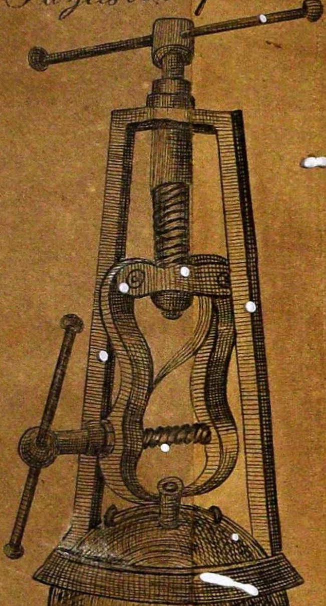
The *French* cover the outside of their pontoons with strong copper plates, and use no lining within, which, in my opinion, is preferable to our method, because copper is much stronger than tin, and is not damaged by rust; and a stump of a tree or any thing that will make a hole in ours will not be able to hurt theirs; and

since

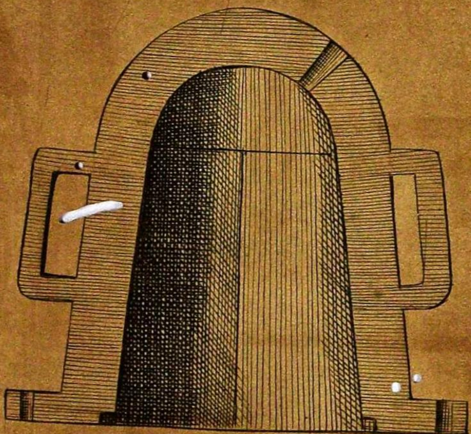
Box with grapeShot

GrapeShot

Engine for drawing the Fuzees out of the Shells



Section of a Petard



ſince we have copper of our own, I cannot conceive the reaſon why we do not follow their method.

The pontoon carriage is as ill contrived as poſſible, for its length is greater than that of any waggon, and yet it is ſupported by two wheels only; they have ſince added a limber to it. The great ſtreſs that lies on the ſhaft horſe, would, one would think, be more than he can ſupport, eſpecially in going down hill, and I have been informed, that twenty men are ſcarcely ſufficient to aſſiſt him; and in going up hill the men are obliged to ſupport the carriage behind, for fear the weight ſhould overbalance that of the horſe. This being ſufficiently experienced in the laſt war, it is ſurpriſing that no artillery officer or artiſt have not contrived a more convenient carriage. The moſt obvious would be to have a limber to it, ſuch as the field carriages have; this the *French* have to theirs, but inſtead of making it with a high bolſter as uſual, I would make the wheels higher, and no bolſter at all, or only as high as the naves, ſo that the pontoon might lie as low as poſſible: by this means the carriage would go with more eaſe, and the ſhaft horſe draw as free as any of the others. To make uſe of two wheel carriages in travelling a great way, and through bad roads, is contrary to ſenſe and reaſon; becauſe the whole weight laying upon two wheels muſt needs make them ſink more in the ground than thoſe of a four wheel carriage, where but half the weight is ſupported by two: it is true that carts may be uſeful in a town at home, where they go upon pavement, and they are beſides cheaper; but that is no reaſon they ſhould be uſed abroad, for which, I dare ſay, they were not intended.

Of the gin. Plate XXVII.

The uſe of this machine is to mount cannons upon their carriages, or to diſmount them: alſo to heave mortars on or from their beds. It conſiſts of three round

round poles of about 12 or 13 feet long, whofe diameters at the lower end are about four inches, five juft below the roller, befides the cheeks that are added to them in that place, and about 3 or 3.5 inches above.

The roller is $7\frac{3}{4}$ inches in diameter, and fix feet long; 20 inches are left fquare at each end for the holes made in them to receive the hand-fpikes, by which the roller is turned; the middle part is made round to wind the cable upon; the two poles, which fupport the roller, are faftened together by two iron bars, the one about 28 inches below the roller, and the other as much above it. Thefe bars are fixed with one end to one of the poles by means of a bolt, and with the other end to the other pole with a bolt and key, fo as to be taken out, in order that when the gin is to be carried abroad, the poles may lay clofe together upon the waggon; fometimes wooden bars are ufed inftead of thefe iron ones, which coft lefs, and anfwer the purpofe as well. There are two iron bands and two iron bolts to faften each cheek to the poles, and likewife iron plates round the poles where the iron or wooden bars are fixed. The poles are hooped at each end, and thofe above have ftraps, through which the iron bolt paffes. This bolt keeps the upper ends together, as likewife ferves to fupport the iron to which the windlefs is hooked: this windlefs contains two brafs pullies, about which the cable goes, which is fixed to the dolphins of the gun or mortar with another windlefs, containing two brafs pullies likewife.

The firft figure fhews the form of the gin, as likewife the dimenfions of the different parts, with all the iron work; therefore it would be needlefs to fay any more of its conftruction. It muft be obferved, that when it is to be ufed, it is laid flat on the ground, the lower end of the fingle pole extends the contrary way, in order to faften the upper windlefs after the cable has been turned round them; after this the upper end is raifed

raiſed gradually till the three poles ſtand nearly at equal diſtances.

The *French* gins differ from ours; *viz.* the two legs, which ſupport the roller, are faſtened together by three wooden bars, nearly at equal diſtances; the third leg is not fixed to the others, but enters into a notch or mortiſe above, ſo as not to ſlip when it is uſed; the upper windleſs is fixed to the two legs by means of an iron bolt, ſo that when they want to uſe the gin, a man gets up by means of the bars, and paſſes the end of the cable round the pullies. This I heard objected againſt, ſaying, that if the gun is mounted near an enemy, it would be dangerous; but as that gin is as eaſily raiſed as ours, they need not climb up, but when they can do it with ſafety.

Of Petards. Plate XXVII.

The *French* petards are made in the form of a fruſtum of a cone, with the vent in the leſſer baſe; in *England* they are made nearly in the ſame manner, only ſome are round towards the ſmalleſt baſe. The ſecond figure ſhews the ſection of one as they are made here; it is 8.5 inches within at the bottom; the diameter at the beginning of the round part is 6, and diſtant from the lower baſe 9 inches; the circular part is deſcribed from the point where the perpendicular to the ſides meets the middle line or axis; the thickneſs of metal is 1.6 inches; there is a brim at the bottom that projects the metal by two inches, and is one thick, in which are ſix holes of half an inch diameter, which ſerve for ſcrews to faſten the petard on a board in a firm manner; there is a cavity within at the bottom half an inch deep, and as much in height, to fix a board, to keep the charge in the petard before it is fixed to the board or plank. There are likewiſe two handles of about three inches from the flat ring, five inches long, ſeven tenths thick, and 1.8 from the outſide to the metal. Laſtly, a hole of an inch dia-

meter is made either at the top or on the ſide, to ſcrew in an iron fuſe to fire the powder by, which fuſe is filled with a ſlow compoſition, in order that when it is lighted, the petardier may have time to retire out of danger.

Petards are made of various dimenſions, ſome larger, and others ſmaller than this; but it may be obſerved that they ſhould not be too heavy, otherwiſe it would be troubleſome to carry them to the gate or ſally port where they are to be fixed; and if they are too little, the effect would not be ſufficient, and therefore would be uſeleſs. In ſhort, the largeſt ſhould not weigh above 70 pounds when loaded and fixed to its plank, and the leaſt not leſs than 45 or 50

It will be eaſy to make any other petard larger or leſs, in proportion to this, whoſe diameter of the baſe is given, by making all the other parts in the ſame proportion; thus, ſuppoſe the given diameter is 10 inches; to find the height between the two baſes, ſay, the diameter 8.5 is to the height 9, as the diameter 10 is to the height required, which will be 10.59 inches, and to find the thickneſs of metal, ſay, the diameter 8.5 is to the thickneſs of metal 1.6, as the diameter 10 is to the thickneſs required, which is 1.9 inches. In the ſame manner the dimenſions of any other part may be found.

The common way of loading the petard, and the beſt in my opinion, is, to fill it gradually with powder, and every two or three inches thick, to put a wooden mould into the petard, which being beat upon with a mallet, ſo as to preſs the powder as cloſe as poſſible, without bruiſing the grains, and when it is quite full, the board is put upon the powder, and over this a cloth with roſin, and bound round the brim with packthread to keep the charge and board together, till the petard is ſcrewed on the plank or board; then the part that exceeds the brim is cut off, and the other being preſſed by the brim, prevents any air coming to the powder.

The board to which the petard is fixed, is about two feet long, 18 or 20 inches broad, and 2.5 inches thick;

it

it has two iron bands on the back, placed cross-ways, and a hook to hang it up against the gate or door, by means of a screw, when it is to be used.

Some moisten the powder with spirits of wine, and dry it in the sun to make it stronger, and then sprinkle every layer of powder of two inches thick with mercury, upon which they lay powder again, and press it down, then sprinkle it again with mercury, and continue so till the petard is filled; but in my opinion good powder alone, well pressed down, is sufficient to produce the desired effect.

Petards have been much out of use since King *William*'s wars, when Mr. *Feuquier* forced open many small towns in *Germany* by their means; but the danger that attends it, has deterred officers and partizans from undertaking such enterprizes. Nor do I find any other nation but the *French* have used them, and even they did not use them in the late wars.

PART VII.

The practice of artillery at home in time of peace, and its service in time of war.

HAVING given in the former part of this work the constructions of the several pieces of artillery now in use, as likewise those of their carriages, in the most concise and easy manner we could, we intend to give here a description of what is practised at home in time of peace, in order to instruct the gentlemen cadets and private men in what they have to do upon the different occasions that may happen in time of war; and then we shall describe the different operations in the field and in a siege, taking the liberty of making observations wherever we think the present practice may be improved;

not with any view of preſcribing rules of my own making, but only to ſet before the judicious reader ſuch things as may poſſibly be of ſervice to thoſe young gentlemen, who have not had an opportunity of learning them in real ſervice; for we do not preſume to offer theſe ſentiments to thoſe experienced officers of artillery, whoſe conduct and courage in the late war, ſo well known to every military gentleman, exempts them from all ſuſpicion of being deficient in any part of their duty.

The practice at home.

In the ſpring, ſo ſoon as the weather permits, the exerciſe of the great guns begins, with an intention to ſhew the gentlemen cadets and private men the manner of laying, loading, and firing the guns, at various diſtances from the but or mark; and as the line of direction is not marked upon the guns, they have a ſmall inſtrument called a *perpendicular*, to find the center line or two points, one at the breech, and the other at the muzzle, which are marked with chalk, and whereby the piece is directed to the target; this being done, a quadrant is introduced into the mouth, in order to give it a proper elevation, which at firſt is gueſſed at, according to the diſtance the target is from the piece. When the piece has been fired, it is ſponged, to clear it from any duſt or ſparks of fire that might remain in it, and loaded: then the center line is found, as before; and if the ſhot went too high or too low, the elevation is altered accordingly. This way of firing continues morning and evening for a month or ſix weeks, more or leſs, according as there are a greater or leſs number of recruits. In the mean time, others are ſhewn the motion of quick firing with field pieces.

REMARKS.

No gun is ever turned ſo true, that the outſide correſponds exactly with the inſide; becauſe, if the bluntneſs of the tools and the heavineſs of the work is rightly conſidered, it will be found morally impoſſible that it ſhould; and the manner of laying pieces, or finding the line of direction, by an inſtrument applied on the outſide, can be but very dubious and uncertain; it alſo miſguides the gunner; for when the *perpendicular* is not always placed exactly in the ſame manner, it will give different lines of directions, whereby he is not able to judge when the ſhot does not hit the mark, whether it is owing to his want of ſkill, or to the falſe direction; and conſequently is never certain whether he underſtands his buſineſs or not. I ſhould imagine, that if the line of direction was marked, as was formerly the cuſtom, with a ſlit or cavity at the breech, and a button at the muzzle, it would be much better; for though this line ſhould not exactly anſwer the direction of the bore, yet when the gunner has once found out its defect, he will eaſily know how to rectify it: this I have ſeen in a piece formerly in *France*, which, when directed at the mark, went a great deal to the left; but the gunners after the firſt ſhot, hit the mark with it as well as with any other.

It is true, that an objection is made againſt this fixed line; for it is ſaid that the platforms are never laid ſo exactly level, but that one wheel will always be higher than the other; and in that caſe the line of direction muſt be falſe. But as I never have ſeen a platform made without a maſon's level, and this is, as far as I know, an univerſal cuſtom, I cannot ſee any foundation for this objection; but let us ſuppoſe that one wheel was a trifle higher than the other, this would cauſe very little error in the direction, which however the gunner would rectify the very next ſhot: but though the platform ſhould be level, it is ſaid the wheels do not always

ſtand exactly in the ſame place, whereby the line of direction is changed every time; this the gunners always take care of, by marking the ſituation of the wheels, and the hind part of the carriage with chalk on the platform. Therefore, ſince the laying a piece with the line of direction upon it, is more expeditious, and at the ſame time more certain, it appears to be preferable to the common practice.

As the quadrant is introduced into the mouth of the piece, merely to know its elevation, and when the ſhot goes either higher or lower than the mark, it is lowered or raiſed by gueſs only, without having any rule to go by, the uſe of that inſtrument can be of no advantage in practice; on the contrary, it prevents the gunner from learning to judge by the eye, what elevation the piece ſhould have according to its diſtance from the object, which he ſhould be able to do when he comes to real action; for which reaſon it ought to be rejected, as well as the *perpendicular*, whether a line of direction is marked on the piece or not.

As the intention of the exerciſe in time of peace, is to render the young artilleriſt ſkilful in all the different branches of his buſineſs, I think, that if faſcine batteries were frequently raiſed, and platforms laid, that they may know how to do it in time of war, and at the ſame time accuſtom the men to fire through embraſures, it would conduce very much to their perfection: for the manner the exerciſe is carried on at preſent upon a ſtone platform, without any declivity, and without breaſt-work, can give no true idea of the firing in a ſiege; the moſt it can do is to repreſent a faint notion of firing in a battle, where no battery or platform is made, except in ſome caſes where a poſt is to be defended. I know an excuſe is made, that it is the duty of the engineers, and not that of the artillery officers to make the batteries, and they have hitherto made them accordingly, as far as I know: yet as this cuſtom is grounded upon very erroneous principles, as we ſhall prove, it ought to be aboliſhed.

abolished. For how seldom does it happen that an engineer in this country has an opportunity to make a battery? and when he has, how shall he know whether the embrasures are rightly made, or what declivity the platform should have, except he is well acquainted with the artillery, or is instructed by the officers of artillery? It may be said, he ought to be acquainted with what has been done by former engineers; but as the length and weight of pieces is changed almost every day, and of course the making the embrasures and platforms must change likewise, it is impossible he should know how to make a battery in a proper manner, unless he was ordered to make experiments every time that pieces are changed, which is never done. Whereas, on the contrary, the officers of artillery are on the spot, and, by firing these guns, have all the opportunity they can wish to determine these things; and to shew the necessity of it, we shall give an instance which makes it evident: formerly, when a 24 pounder weighed from 51 to 52 hundreds, and its length was 10 feet, the platforms were then made 18 feet long, and 9 inches higher behind than before; and now we make 24 pounders, that weigh but 17 hundreds, and whose lengths are 5 5 feet; and as it may happen that these pieces are used upon a battery, how should an engineer be able to raise one properly? and if he makes it as customary, the guns will run off their platforms every time, by which the service will be retarded, and who is to be blamed? not the engineer, as I conceive, since he had no opportunity to try these pieces before-hand. Again, the diameter of the wheels for heavy gun carriages is 58 inches, and that of the light pieces 50 only; so that the height of the embrasures must be made less for the latter than for the former. The distance of the battery from the object depends on the range of the pieces; and as the light carry not so far as the heavy, by reason that their charges are less, a battery for the light pieces must be nearer the object, than that for the heavy. And since

no one can be a better judge than the artillery officers, who daily practise them, they are therefore the properest to direct the making of batteries.

As the word *point blank* is often misunderstood, we shall endeavour to define it here according to the general and proper acceptation; which is, suppose a piece stood upon a level plain, and laid level, then the distance between the piece and the point where the shot touches the ground first, is called the *point blank range* of that piece; but as the same piece ranges more or less, according to a greater or less charge, the *point blank range* is to be understood to be that, when the piece is loaded with that charge, which is used commonly in action. It is therefore necessary that the ranges of all pieces should be known, since the gunner judges from thence what elevation he is to give to his pieces, when he is either farther from or nearer to the object to be fired at, and which he can do pretty nearly by sight, especially if he has practised it often.

Ricochet firing is likewise necessary to be practised, that is, the pieces are elevated from three to six degrees, and loaded with a small charge, in order that the ball may be bound and roll along the inside of the parapet; for which reason a front of a polygon should be made, to shew the gunners clearly the object of these batteries, and to try and find the charges for various distances; but as no work of this kind has hitherto been made (though according to the instructions of the academy there should) piquets or stakes might be placed at proper distances, to represent the traverses or the angles of the front of the polygon, which will answer the purpose nearly as well as if there were real works. As this method of firing saves a great deal of powder, and is more dangerous than the usual way, as will be shewn hereafter, it ought by all means to be practised in time of peace.

Mortar

Mortar practice.

After the gun exercise is over, that of mortar begins, and sometimes they are carried on both together; the usual manner is thus; a line of 12 or 1500 yards is traced in an open spot of ground, from the place where the mortars stand, and a flag fixed on the end; this being done, the ground where the mortars are to be placed is prepared and levelled with some sand, so as they may stand at an elevation of 45 degrees; then they are loaded with a small quantity of powder at first, but increased afterwards, by an ounce every time, till it is loaded with a full charge: the times of the flights of the shells are observed, to determine the length of the fuses.

The intention of this practice is, when a mortar battery is raised in a siege, to know what quantity of powder is required to throw the shells into the works at a given distance, and to cut the fuses of a just length, that the shell may burst as soon as it touches the ground. This is certainly a very good method, with regard to its intention; but in a siege shells are not or never should be thrown with an angle of 45 degrees, but in one single case only, which scarcely ever happens, that is, when the battery is so far off that they cannot otherwise reach the works. For when shells are thrown from the trenches into the works of a fortification, or from the town into the trenches, they should have as little elevation as possible, in order to roll along, and not bury themselves, whereby the damage they do, and the terror they cause to the troops, is much greater than if they sink into the ground. On the contrary, when shells are thrown upon magazines, or any other buildings, with an intention to destroy them, the mortars should be elevated as high as possible, that the shells may acquire a greater force in their fall.

It is said that howitzes are made to throw shells with a small angle of elevation, and therefore it is not necessary to use mortars for that purpose, and that an angle of 45 degrees is sufficient in a bombardment; which may likewise be done with less powder than at any other elevation.

Granting this, I should be glad to know the use of mortars, at least of the small; since no less than 13 inch are or ought to be used in throwing shells upon magazines, and even those are not always sufficient to break through the arches of powder magazines; therefore it would be needless to carry any smaller to the field. But the true reason is, our mortars are immoveably fixed to their beds, and the custom has prevailed for some years, to lash them strongly with ropes to their beds, which could not be done if they were moveable, and the belief that without this lashing they would kick up before, and fall backwards when fired. But to convince the reader of the insufficiency of this reason, he must know that the *French* never lash their mortars, though they are much shorter and lighter than ours, and often fire them with an angle of 75 degrees, without their ever falling back, as we absurdly imagine. This is demonstrable without having recourse to any experiments; for we have shewn that confined powder acts every where alike when fired, but being resisted in pieces of artillery on the sides by the strength of the metal, the shot is driven forward, and acts likewise on the opposite part so as to make the piece recoil. Now as action and re-action are always equal and opposite, whilst the action on the upper part of the chamber endeavours to raise the mortar, that on the under side opposite to the other acts with the same force downwards; and therefore these two forces being equal, and in opposite directions, they destroy each other. Hence, there is not the least occasion to lash the mortars to their beds, nor fix them immoveable, as hitherto has been the custom.

N. B.

N. B. What we have said here relates to land mortars only; for those on board bomb-vessels are so heavy, and the motion of the ship so variable, that it would be needless to attempt any other method than what is used.

In firing mortars no wadding is used here upon the powder, in order that the blast of the powder in the chamber may light the fuse of the shell by means of a quick match; on the contrary, the *French* put a wad upon the powder, and fill the rest of the chamber with earth; and when the mortar is fired, one gunner fires the fuse, while another fires the powder in the chamber. But as the fuse might by chance take fire before the powder, the shell might burst in the mortar, spoil it, and endanger the lives of the men, and as the earth can make but very little resistance, the powder acts nearly with the same force as if there was none; therefore this method is very defective, and much inferior to ours.

Instead of loading mortars with loose powder, as is the custom, I would chuse to use cartridges as well as in guns, for the following reasons; because when the powder lies loose, its surface spreads near horizontally, so that the lower part lies nearer the shell than the upper, which makes its effect much less than it would be were it confined; neither can the chamber be filled with as much powder as it can hold, for which reason they are always made larger than they should be, whereby the effect is never so great as it would be otherwise; thus, in our thirteen inch mortars the chamber holds nine pounds of powder, whereas it is well known that six pounds is the most that is wanted; and since loose powder never acts with that force it does when confined, it is evident, that the firing mortars with loose powder is not so advantageous as when they are fired with cartridges. Another advantage this manner has over the other is, that when the chamber is not filled, the cartridge may be left close to the shell, and the empty space

at

at the bottom of the chamber, whereby the powder acts with more violence than if the powder was at the bottom of the chamber, and the empty space near the shell; this colonel *Desaguliers* and myself tried many times with half the charge, and the range was always nearly double in the first case than in the second. When the powder is loose in the chamber, if a piece of writing paper be put over it to keep it up, it will make a greater range than otherwise: all this confirms, that with less powder a greater effect may be produced, than with a greater quantity, which ought not to be neglected.

We have shewn the inconveniency of fixing mortars to their beds so as not to be moved, because they never will produce the effect that might be expected; we shall add another reason, which is, that when the charge is the same, and the elevation varies, the rules of projectiles may be used, which, though deduced from the theory of bodies moving in a non-resisting medium, and the resistance of air is considerable in swift motion, yet they will give the ranges very near under 1200 yards; for which reason we shall set them down here, leaving it to practitioners to try them, or let them alone, as they think proper.

Practical rules for horizontal ranges.

I. *The range of a body projected with an angle of* 15 *degrees, is half the range of that body, if projected with the same force with an angle of* 45 *degrees.*

II. *The range of a body projected with an angle of* 45 *degrees, is equal to the square of the time of its flight, expressed in seconds multiplied by* 16.1 *feet.*

III. *If a body be projected with the same force, but with different angles of elevations, the horizontal ranges are as the sines of angles double those of the elevations respectively.*

IV. *The*

∴ *The times of the flights of the ſame body, projected with the ſame force, with different degree of elevations, are to each other as the ſines of the angles of elevations.*

Theſe rules are demonſtrated in my Elements of Mathematics, Book the fourth, Section the third.

EXAMPLE I.

Let a body projected with an angle of 45 degrees of elevation be 12 ſeconds in its flight, what is the horizontal range?

The ſquare of 12 is 144, which multiplied by 16.1, gives 2318.4 feet, or 772.8 yards, by rule the ſecond, for the range required.

EXAMPLE II.

If the range of a body projected with an angle of 25 degrees be 200 yards, what will be the range if the body is projected with the ſame force under an angle of 30 degrees?

The ſine of 50 degrees, double of 25, is 76604; and the ſine of 60, double of 30, is 86602; therefore 76604 : 86602 : : 200 : 226, equal to the range required by the third rule.

EXAMPLE III.

If the range of a body projected with an angle of 20 degrees be 200 yards, what muſt the angle of elevation be to project the body with the ſame force at a diſtance of 300 yards?

The ſine of 40 degrees, double of 20, is 64278; whence 200 : 300 : : 64278 : 96417, equal to the ſine of the angle double the required one: this ſine anſwers

to

to an angle of 74 degrees 37 minutes, half of w…
is 37 degrees 18.5 minutes, for the angle sought.

EXAMPLE IV.

The horizontal range of a body projected with an angle of 45 degrees being 1000 yards, to find the time of its flight?

Then say, as 16.1 feet is to the given distance 3000 in feet, so is unity to the square of the time required, which is 186, whose square root 13.6 seconds will be the time required.

EXAMPLE V.

If the time of flight of a body projected with an angle of 45 degrees is 20 seconds, what will be the time of the same body projected with the same force with an angle of 35 degrees?

As the sine of 45 degrees is 70710, that of 35 degrees 57357; whence 70710 : 57357 : : 20 : 16, equal to the time required.

This last example shews how to compute the time of the flight of a shell when the range can be measured, and from thence the length of the fuses; as likewise at sea, where the distance is known from the mortar to the object, the time being computed when a shell is thrown, it may be known whether it fell short, or goes beyond the object, according as the time observed of the flight is less or greater than the time computed.

These are nearly all the different exercises of the artillery in time of peace, except that the men are shewn sometimes how to take the guns off their carriages, and to put them on; whence the reader may see, that the artillery art is chiefly reduced to fire guns and mortars; but as these exercises are soon over, and a great deal of time

time is ſpent in doing very little, which generally makes the private men get idling about, ſpend their money, and do miſchief for want of other employment, I propoſe the following ſcheme to employ them for the good of the public, without any hardſhip to them.

When all the field exerciſes and that of ſmall arms are over, and nothing to be done, a detachment of private men, commanded by young officers, conſiſting of about a ſixth part of the garriſon, ſhould be ordered to attend the laboratory, to make and prepare all kind of military ſtores that are neceſſary, during three hours in the morning, and three in the afternoon; at other times they ſhould be employed to make fireworks for the uſe of artillery, and for rejoicings; this would be no hardſhip upon the ſoldiers to be employed once a week for ſix hours, the officers would have leſs trouble to keep them clean and ſober; they would likewiſe know how to prepare thoſe ſtores when they are wanted to be ſent abroad, where there is no laboratory, and yet neceſſary to be had. Laſtly, great expences would be ſaved to the public, without any hardſhip or detriment to any body.

This would alſo be a means to inſtruct the young officers in that branch of their buſineſs, of which they ſhould not be ignorant: for how often does it happen, when a detachment is ſent to the *Eaſt* or *Weſt-Indies*, where having powder, ſhells, and ſhot, it is neceſſary to make grape ſhot, fill the ſhells, and drive the fuſes; or after having gained a victory, to make fireworks for rejoicing; now if an officer does not know to order how theſe things are to be done, what a figure muſt he make before a commander in chief, who requires it of him, and expects he ſhould be able to do it!

I think it alſo neceſſary that an artillery officer ſhould know the names of every thing neceſſary for a field equipage, eſpecially of all the parts of a gun, a mortar, and their carriages; for if any accidents happen in a ſiege, how can he ſend word to the workmen, who are

generally

generally in or near the park of artillery, of what is wanting? for they, not knowing what is broke, must come perhaps a mile to see it, and go back again to fetch it; in the mean time the piece cannot be fired, whereby the service is retarded.

It appears also to be necessary upon many occasions, that the officers should be acquainted with the principal constructions of gun and mortar carriages; for it may happen, that when they are sent upon an expedition to the *East* or *West-Indies*, where either new carriages may be wanted, or old repaired, they may always find wood and iron; as likewise smiths and carpenters in the country, but who not being acquainted with this kind of work, if he knows how to direct them, it will be both an advantage to him as well as to the service: it may be said, that there are always workmen sent with those detachments by the board of ordnance, whose duty it is to do those things; but if those artificers should die, which may happen, what must be done then? if the officer does not know how to direct others, the consequence will be, that the service must be retarded, and who will be blamed?

It is likewise very material, that an officer should know the quantities of stores and their kinds that are required upon any expedition. It is true that this detail is commonly made out at the Tower; but if by mistake any materal article should be omitted, when he comes to an action and wants it, the commanding officer would blame him, and not those that sent them.

The service of ARTILLERY *in a land engagement.*

The pieces are generally placed upon some rising ground before, and at the sides of the first line, where the enemy is supposed to make the greatest effort, or in some village, garden, or near some hollow way through which he can march; and as they are to advance or retreat, according as the army moves and the enemy approaches,

approaches, there is no time for raiſing batteries, except a ſpot of ground is taken poſſeſſion of the night before, which is advantageous for covering either a wing or the center, and neceſſarily to be kept and defended; the heavieſt pieces ſhould be placed there, and the others in the moſt advantageous manner the ground will admit of: every time they are fired the men advance them to the ſame place again; ſo that when the guns are once pointed right, they continue ſo all the time they remain in the ſame place. Our preſent light pieces are wonderfully well adapted for this ſervice, the men being able to move them as they pleaſe with very little trouble, and the ſcrews uſed to keep them at the ſame elevation are much more convenient than the coins which were uſed before, becauſe they fly off every time the pieces are fired.

At firſt the guns are fired with balls, but when the enemy comes near, they are then loaded with grape ſhot. In this caſe the charge ſhould not be ſo much as before, becauſe it has been found by experience, that when the charge is great, the ſhots ſpread too much, by ſtriking againſt each other, whereby many of them do no execution, which ſhould be avoided if poſſible. In my opinion a ſixth part of the weight of the ſhot will be ſufficient upon this occaſion. But when pieces are loaded with balls, one fourth, or perhaps one fifth will be the proper charge, ſince no more was uſed in our light pieces during the laſt war.

It has been obſerved by ſeveral artillery officers, that howitzes might be uſed in an engagement to very great advantage, if they were placed in the flanks, ſo as to fire obliquely upon the enemy's line, or amongſt their horſe, when loaded with ſmall charges, that the ſhells may roll and bound along, whereby a great diſorder would enſue among them; which being perceived, if they are briſkly charged, might be the means of gaining the day. For it muſt be obſerved, that cannon ſhot paſs ſo ſwift through the ranks, that men are killed

without ſeeing the danger, which the reſt look upon as an accident attending their buſineſs; but when they perceive the ſhells rolling along with their fuſes burning, and expecting them to burſt every moment, the braveſt amongſt them will hardly have the courage to wait for their coming near him.

When pieces are fired with cartridges, the bottoms will remain in them whatever care can be taken; they muſt therefore be drawn from time to time, or elſe they will accumulate ſo that the tube cannot reach the powder. The ſhorteſt way of doing this, is to fix a worm at the head of the ſponge with a good ſpring, ſo as when it is preſſed upon, it may ſponge the bottom of the piece, and draw out the remaining bottom at the ſame time; for all other methods propoſed by ſome artiſts are inſufficient. Another method I think might likewiſe do, is to pierce the vent from behind the breech, in the manner the *Saxon* guns were, whereby the tube cannot miſs to reach the powder, provided it is of a ſufficient length: beſides, the cartridge being pierced in the bottom, ſome grains of powder may probably fall between the cartridge and the end of the bore, and ſo blow out the bottom with the reſt.

It is to be obſerved, that the powder carts ſhould be near the batteries, not only to ſupply them with powder, but likewiſe the troops near them, when that which they receive before the engagement is all ſpent; becauſe batteries are objects or marks of ſuch a nature as to be known at a great diſtance, whereas, when the powder is placed any where elſe, the troops do not know where to find it if they are in want. But at preſent every battalion has two field pieces to attend them, which I ſuppoſe have powder carts along with them, that contain a ſufficient quantity to ſupply the battalions.

The

The service of ARTILLERY *in an attack.*

The first batteries erected in an attack are generally placed about a hundred yards before the first parallel upon a rising ground, if there is any that lies conveniently, and as they commonly are made for ricochet firing, must be at right angles to the faces produced of the works in the front attacked, and there being eight faces in the front, when there are ravelins and a covert-way, so there must be eight batteries, each of four guns at least, besides some mortars placed in the same batteries.

When ricochet firing is used, the pieces are elevated from three to six degrees, and no more; because if the elevation is greater, the shot will only drop into the work, without bounding from one place to another; they are to be loaded with a small charge, and directed in such a manner as just to go over the parapet.

Mr. *Vauban* says, that half a pound of powder is sufficient for a 12 pounder in most cases; which is one twenty-fourth part of the ball's weight: therefore where-ever this firing can be practised, it should be done, since it saves much powder, and the pieces will not be heated let them be fired ever so much. The same batteries will likewise serve to dismount the besieged guns placed in the faces opposite to them; but in that case the charge must be one fourth, or one third of the shot's weight. The chief engineer and the commander of artillery consult together how to place these batteries, and when the places are fixed upon, the pioneers are set to work, under the command of an artillery officer in the *French* service, where they have a particular number called commissaries, who are not attached to the regiment of artillery, and when the ground is thrown up, the gunners make the inside facings with fascines themselves, as likewise the embrasures, and lay the platforms; for nobody can be a better judge how to do this work than

they, and therefore they ought to practise it in time of peace, as we have observed before.

The next batteries to be raised are those for making breaches, and to destroy the flanks: the first are placed upon the glacis, within 18 or 20 feet of the covert-way, directly opposite to the faces in which they are to make breaches, and the others also upon the glacis at the same distance from the covert-way, opposite to the ranks. This distance is left for the thickness of the breast-work or parapet.

It has been customary to charge the pieces with half the weight of the shot; but experience has shewn, that one third or less is sufficient; for provided that the shot just enters the wall, the effect will be greater than when it penetrates a great way. The manner of making a breach is to fire at first as low as possible, and to direct the pieces so as to hit in an horizontal line near each other; if they are fired together, and not one after another, the shock will be the greater.

The reason for battering so low is, that if the wall is cut low in an horizontal line, the part above falls down all at once; whereas if the wall above is beat down at first, the rubbish covers the lower part in such a manner, as not to be destroyed afterwards, and without which the breach becomes impracticable. When the wall is once beat down, it will be advantageous to fire shells into the earth, for each shell will produce the same effect as a little mine; whereas the shot will only make a hole of its own bigness, without any great effect. It has been found that the vents of battering pieces have been so much spoiled in a siege, as to render the guns unserviceable: this may be prevented by firing with tubes, as in quick firing it has been found by experience that they preserve the vent, for we fired a six pounder 300 rounds in 3 hours and 27 minutes, without widening the vent in the least; consequently this manner of firing saves great expence, since the same guns may serve in many

many sieges, without having them recast, as was the case heretofore.

The antients made use of much larger calibers for battering pieces than we do; they knew very well that the breach is sooner made with them; but they imagined that the greater the force was, the quicker the work was done; for which reason they loaded their guns with as much powder as the shot weighed; and as the strength of the guns was made in proportion to the effort they sustained, they became so very heavy, as hardly to be managed; for which reason none but 24 pounders are used at present, whose strength is made so as to bear a charge of two thirds of the shot's weight; and though experience has shewn that one third was sufficient, yet their weight has not been diminished.

This was the reason that induced us to make the battering pieces lighter, for we made the thickness of metal but three quarters of the shot's diameter at the vent, instead of a whole diameter, as in the present. And as the strength of a piece is in proportion to the thickness of metal, that of ours will be to that of the present pieces, as 3 to 4; and the forces being nearly as the quantities of powder, ours will be acted upon but with half the force of the old; and consequently their strength is more than sufficient upon all occasions.

Now as our new 42 pounder weighs 47 : 1 : 0, and is 10 feet long, and the old 24 pounder weighs about 51 : 0 : 0, and is only 9.5 feet long, we conceive that our new piece is much preferable for making a breach to the old 24 pounder. For it enters farther into the embrasures by six inches, and of consequence does not destroy them so soon; it requires no more men to manage it, and no more horses to draw it; and as it will sooner make a breach, there can be no comparison made between their usefulness. As to the charge, I would never use more than ten pounds of powder, for the forces of shots are in proportion to their weight multiplied by the weight of the powder; whence a 42 pounder

der loaded with ten pounds of powder will produce a force, which is to a 24 pounder loaded with the same charge, as 42 to 24, or as 7 to 4. This is the particular excellency of large calibers, that they produce a greater force with less powder in proportion; and consequently they are much preferable in most cases. And they have another advantage, which is, when you fire at a distance with a proportionable quantity of powder, the resistance of the air is reciprocally proportional to the diameters of the shots nearly; thus the diameter of a nine pound shot is 4 inches, that of a 49 pounder 7 nearly; and therefore the resistance of the 9 pounds is to the resistance of the 49 pounds, as 7 is to 4 nearly. Whence it appears, that the first will meet with a resistance near double that of the second.

Construction of batteries.

To make a battery before the face of a vigilant enemy strong and durable, and to use no more materials and workmen than are necessary, is perhaps the most important work in a siege: though the enemy do not know their situations, yet may guess where they should be, and prepares his fire accordingly; and so soon as he hears the least noise of workmen, will do all he can to annoy them both by his fire and sallies; being sensible that when they are once made they will destroy all his defences, and dismount his guns; and when that is effected, the approaches may be carried on without any other obstacle than the fire of small arms, against which the workmen may easily cover themselves.

To proceed with order, the quality and quantity of the materials, as well as the number of workmen and their tools, must be determined as exactly as the nature of the subject will admit. From the known dimensions of a battery, the quantity of the materials may be determined and their kind from their situation. For the parapet or breast-work is 18 or 20 feet thick, and 7.5

of

of 8 feet high; each gun takes up 18 feet parapet, and each end about 10: the embrasures are 3 feet from the ground, 2 feet wide within, and 15 or 16 without; so that the merlons or part between the embrasures are 16 feet long on the inside, and 4.5 or 5 feet high.

The dimensions of the fascines are various, but the following are in my opinion the most convenient in many respects; their diameters should be 10 inches or circumference 31.5, and their length 10.8 and 6 feet: because one of 10 feet and one of 8 make the thickness of the parapet; one of 10 and one of 6 the merlons; one of 10 the ends; and one of 10 and 8 the inside of the embrasures: lastly, 9 layers make up the height of the parapet. Another advantage of the above lengths is, that the ends of one layer will not be over those of the next above it, and they are made and carried with more ease than those that are longer, such as the *French* generally use.

Hence a battery of two pieces will be 40 feet long, and requires two fascines of 10 feet, one of 8, and two of 6 for each layer from the ground to the embrasures, and four layers 8 of 10, 4 of 8, and 8 of 6 feet, which are required for that height; because four layers make 40 inches in height, and the under one being sunk about 4 inches into the ground, there remains 3 feet.

The distance between the two embrasures being 16 feet, requires one of 10 feet, and one of 6, and each end one of 10, that is, three of 10, and one of 6 for each layer; and if we take 6 layers, 18 of 10, and 6 of 6, which makes the parapet 8 feet high; though 5 layers will be sufficient on most occasions, yet it is proper to have some spare fascines.

As the embrasures are likewise to be secured with fascines, each layer requires one of 10 feet, and one of 8; so that the six layers require 6 of 10, and 6 of 8 feet; and as two embrasures require four times that number, that is, 24 of 10, and 24 of 8; to which must

be added one to lay over each embrasure of 6 feet long, to cover the gunner against the plunging musket shot; which two added makes 24 of 10, 24 of 8, and 2 of 6, for the number of fascines required for the embrasures. The ends of the parapet, are likewise supported with fascines, one of 10 feet, and one of 8: and the ten layers 10 of 10, and 10 of 8; and both ends 20 of 10, and 20 of 8 feet long.

So that a battery of two pieces requires 70 of 10, 48 of 8, and 16 of 6 in all. When a battery is enfiladed by some of the outworks, they must have flanks from 10 to 12 feet thick, and 18 long, which requires 10 fascines of 10 feet, and 10 of 8 each flank; and when the soil is sandy, it is scarcely possible to keep up the earth on the outside without fascines, at least from the berm to the embrasures; for which it requires 8 of 10, 4 of 8, and 6 of 6, in any battery of two pieces.

Besides these battery fascines, others of a smaller size are required, which I shall call *bavins*, to lay along the rope which traces the plan of the battery, and confines the earth till the other fascines are laid and picketed; as likewise to cover the powder magazines: their diameter may be 5 inches only, and length 6 feet. These magazines must hold as much powder as is expended in a day; supposing a 24 pounder to fire 100 rounds in a day, and loaded with 8 pounds each time, requires 800 lb. or 8 barrels; and as a barrel is about 15 inches diameter, and 30 long, 3 bavins will cover one; and as they are placed one over another, 12 bavins will cover the powder of one 24 pounder.

As it is also necessary to support the ends of the fascines in the front, the others being laid upon the bank of earth, and an upright post when the magazine is large: they are sometimes covered with planks when they can be had.

The length of platforms are commonly 18 feet, 8 broad before, 15 or 16 behind; the planks a foot broad, and from 2 to 2.5 thick. The hurter to stop the wheels

from

from damaging the fascines is 5 by 6 inches square, and 8 feet long. There are five sleepers to each platform to lay the planks upon, 3 by 4 inches square, and 18 feet long; each sleeper is fastened by pickets drove fast in the ground, two at each end, and two in the middle; and the last plank by 4 to keep them close together: there requires then 34 pickets for each platform.

The fascines must be well bound, those of 6 feet by 3 bands, of 8 by 4, and of 10 by 5: the length of the pickets to pin down the fascines must be from 3 to 5 feet, the diameters of the heads from 2 to 3 inches, well squared at the heads, and sharp at the points. There are three required for a fascine of 6 feet long, four for one of 8, and five for one of 10; which makes 590 pickets in all for a battery of two pieces.

A soldier may make 12 battery fascines a day with the pickets required, when proper wood is to be had conveniently: a horseman may make 20 bavins a day, bound in two places only, because they require very little care to make them neat; for it is the cavalry that generally make these kind of fascines.

Twelve soldiers will make a sufficient quantity of fascines in a day for a battery of two pieces, and three horsemen a sufficient quantity of bavins at the same time. Each man must be provided with a hand-bill and two hatchets for the whole detachment to cut the branches from off the trees.

In the construction of a battery of two pieces, it requires 10 mallets to drive the pickets, 15 spades, shovels, and pick-axes for digging, according to the nature of the ground. It has been found that 50 men are sufficient to make a battery of two pieces in one night, 70, 90 for one of 4 or 6 pieces.

The following table contains the number of men, their tools and materials, to construct in one night batteries from 2 to 20 pieces of cannon, as nearly as we could compute them; but as it is convenient to have some fascines and pickets to spare, and to repair the battery,

battery, we ſhall leave it to the engineer to make what allowance he pleaſes. We have not inſerted the number of faſcines and pickets required for the flanks; and if there are any, their number determined above muſt be added. We have neither marked the number of men or materials for batteries of an uneven number of pieces, becauſe they may be eaſily found, by taking half the ſum of the next greater and leſs, to have the number that is wanted.

Ricochet batteries.

Formerly batteries were made at the opening of the trenches to protect the workmen, but ſo ſoon as the firſt parallel was made they became uſeleſs; and as they are expenſive to make, and require much time and labour, this method has been rejected; and now none are made before the firſt parallel is finiſhed. Beſides, the approaches are now made the firſt night as far as the firſt parallel, and the parallel itſelf ſo far as to be finiſhed and perfected the next day; and when that is done, the batteries are erected about 100 yards before them perpendicular to the faces produced, which they are to enfilade: when they are compleated, do remain till the ſiege is finiſhed. Theſe batteries ſerve likewiſe to diſmount the guns placed on the other faces nearly oppoſite to them.

As the beſieged will ſpare no pains to fire upon the workmen, and retard their conſtruction as much as they can, I would adviſe the engineer to continue the trenches of communication from the parallel to the battery by ſap quite round it, in taking care to leave a ſufficient ſpace for the ditch before the battery to get the earth for making the parapet: then the workmen may go on night and day till the whole is finiſhed with very little danger.

Theſe firſt batteries muſt be made as ſubſtantial as poſſible, in order to reſiſt all the fire the beſieged can bring

bring upon them: as they are too far from the works of the fortification, they can ſcarcely be enfiladed, and therefore require no flanks.

Batteries on the glacis.

These batteries are made to make a breach in ſome of the outworks, or in the faces of the baſtions, and to deſtroy the flanks; and as by this time the beſieged cannons have been or ſhould be diſmounted, except thoſe placed in the flanks, their parapets need not be above 10 or 12 feet thick; and as by this time the trenches are advanced upon the glacis within 12 or 15 feet of the covert-way the batteries are placed in them; by which leſs labour, leſs materials, and leſs workmen are required: but as they are generally ſeen in the reverſe, they require flanks againſt the fire of ſmall arms. Sometimes approaches are made uſe of to place batteries in them; in ſuch caſes they are widened backwards as far as is required for the recoil; and if the approaches are too deep, the bottom muſt be raiſed to a proper height with faſcines and earth to place the platforms upon them; and the parapet or breaſt-work muſt be made of a ſufficient thickneſs, and lined with faſcines in the ſame manner as mentioned before.

Mortar batteries.

They differ from the former in having no embraſures, and may be ſunk into the ground: ſo that whilſt the workmen without, throw the earth inward to make the parapet, others within, may work to throw the earth forward; by which the parapet is much ſooner compleated than thoſe of cannon: the inſide ſlope ſhould be conſiderable, that the bombardier may place two pickets, one at the top, and the other about the middle, in order to mark the line of direction for each mortar.

The

The platforms are about 6 feet ſquare, 8 diſtant from each other, and as much from the parapet, ſloping forwards, and are compoſed of 6 planks of 6 feet long, one broad, and 2 or 2.5 inches thick, 4 ſleepers, and about 28 pickets. As our mortar beds are made of ſolid timber, they commonly make a bed of gravel and ſand inſtead of a platform; but this method is diſapproved by the moſt experienced officers, eſpecially in ſieges.

When mortars are placed in the approaches, it is only widened ſo much as to have room for the loading and firing the mortar, and the earth dug up ſerves to heighten and thicken the parapet without any other preparations.

Battery in a moraſs.

To find a convenient ſpot of ground in ſuch ſituations, as likewiſe to make a road for the cannon and ammunition firm and ſecure, meets often with great difficulties, and ſeldom can be done but on or near the cauſeway that leads to the town; and if the place is properly fortified, it has always a flank that enfilades the cauſeway from one end to the other: in that caſe a battery muſt be raiſed near enough to diſmount the guns of the place, in order to carry on the approaches by zig-zagues on the cauſeway, till you come within a reaſonable diſtance to make a breach: the ſituation of the battery being fixed upon, faſcines, ſtone, and earth muſt be thrown in to make the foundation of the breaſt-work and platforms; when this is done to a proper height and levelled, the reſt of the parapet is finiſhed with gabions, ſome of 4 feet diameter, and as much in height; and others 3 feet high only for the embraſures.

It requires 10 for the firſt row in a battery of two guns, and 5 for the thickneſs of the parapet, that is, 50 gabions for the under bed. The row towards the town muſt be placed firſt, and filled with earth brought in baſkets and ſand-bags, or elſe theſe gabions muſt be ſtuffed with wood; then the next row is placed cloſe to

to the firſt, and filled as quick as poſſible; and when another row is placed over the middle of the two firſt and filled, the workmen will be covered againſt the fire of the ſmall arms. When this is done the embraſures are marked, and gabions placed all round the merlons, beginning always with thoſe towards the place; or elſe the embraſures may be made with faſcines as before: and then the inſide or coffers may be filled with gabions, bavins, or faſcines, and earth to fill up the intervals, and make the parapet ſtrong and ſolid. If the height of two gabions is not ſufficient, faſcines and earth may be uſed to make up the deficiency.

The beds of the platforms are made with faſcines, and earth over them, ſo as to make it ſmooth and firm; and if that is not ſufficient, hurdles may be laid upon that bed, and more earth, and then the platforms in the manner as deſcribed before: when the whole is finiſhed, and the faſcine over the embraſures fixed, the gabions that maſk the embraſures are taken away, or elſe puſhed with a pole into the ditch before it, or ſo as not to prevent the ſeeing the defence of the place.

If there is no ſituation near the cauſeway, where the battery can be placed to make a breach, or to diſmount guns which may ſee the breach, there is no other remedy than to carry a road made of faſcines, hurdles, and earth, either from the cauſeway, or the neareſt firm ground to the place where the battery is to be made.

It happens ſometimes that the ground where the battery can be made is ſeen by a ſuperior battery, that will diſmount the guns of yours; in this caſe a breaſt-work muſt be made at 20 or 30 paces before your battery, and embraſures cut in it ſo as that you may fire through, and prevent the beſieged from diſmounting your guns: this may always be done if there is ever ſo little bias, as it happened at *Oſtend*, when beſieged in the former war by the *French*. There was a ſpot of ground above the water, which overflowed all the adjacent ground when the tide was in: from this ſpot the harbour could

be

be enfiladed. Upon the fall of the adjoining baſtion to the harbour were placed fourteen 18 pounders, which bore obliquely upon the *French* battery of ſix 4 pounders; but by raiſing another breaſt-work about twenty paces behind the firſt, they fired during the whole ſiege into the harbour, without being ſeen or diſturbed by the ſuperior battery of the beſieged.

Battery upon a rock.

Such a ſituation is the moſt difficult of any, becauſe there is in many caſes no earth to be found but at a great diſtance, ſo that the parapet muſt be made with ſtuffed gabions and blocks of wood; the platforms partly cut out of the rock with pick-axes, and partly filled with earth and faſcines: and if the ſituation is ſeen by the beſieged guns, which can ſcarcely be avoided, and the battery not finiſhed in a dark night, it muſt be maſked with large trees or palliſades, otherwiſe the beſieged will pour all their fire upon the workmen, to make it in a manner impoſſible to finiſh it; ſince the ſplinters of the rock are no leſs dangerous than the ſhots.

If there is no road to the rock but what paſſes near the place, the firſt thing to be done is to convey the cannon and ammunition before the beſieged have any notice of your intention, otherwiſe they will oppoſe all they can to prevent it; and if they cannot, will render the paſſage ſo dangerous, as ſcarcely to make it practicable.

The ſituation of batteries is generally determined by the object to be battered, yet the advantage of the ground is often taken, ſuch as a hollow, hedge, buſhes, or old building, if the beſieged have neglected to clear the ground; but care muſt be taken that the battery is not too obliquely to make a breach, as it happened at *Carthagena* in 1742, where a battery of twenty 24 pounders was made in a copſe, and when finiſhed its ſituation was ſo bad, that after a week's firing the breach was ſo little, that a ſingle man could not mount it with-

out

Number of Men, Tools, Fascines, Pickets, and Planks for making BATTERIES, *from two to twenty Pieces of* CANNON, *in one Night.*

Numb. of Pieces.	Length of the Battery	Men to make the Battery	Men to make the Fascin.	Tools.	Fascines in Feet. 10	Fascines in Feet. 8	Fascines in Feet. 6	Pickets	Mallets	Hand Bills.	Platforms. Planks	Platforms. Sleeper	Platforms. Pickets	Bavins.
2	40 Feet	50	15	70	70	48	16	590	10	12	36	10	68	50
4	58	70	25	100	120	76	32	1000	18	16	72	20	128	100
6	76	90	35	130	170	104	48	1410	26	20	108	30	192	150
8	94	110	45	160	220	132	64	1820	34	24	144	40	256	200
10	112	130	55	190	270	160	80	2230	42	28	180	50	320	250
12	130	150	65	220	320	188	96	2640	50	32	216	60	384	300
14	148	170	75	250	370	216	112	3050	58	36	252	70	448	350
16	166	190	85	280	420	244	128	3460	66	40	288	80	512	400
18	184	210	95	310	470	272	144	3870	74	44	324	90	576	450
20	202	230	105	340	520	300	160	4280	82	48	360	100	640	500

out being supported. At *Minorca* the *French* made a battery under cover of some empty houses; and at the *Havannah* we made batteries against the fort *Moro* under cover of a wood. But when there is no cover, and you are obliged to make a battery near the enemy, the best method is to raise a great heap of earth by way of a cover, and make the battery behind it; and when it is finished, the earth is pushed forward in the ditch, if there is any.

To secure the gunners against the fire of small arms whilst they are loading the guns, shutters are made the width of the embrasures, either sliding in grooves, or fastened with hinges, so as to open or shut as occasion requires. As to the rest we refer the readers to our attack and defence, page 38, where they will find a plan, and a further explanation of every thing necessary not mentioned here.

PART VIII.

Calculation of the quantity of ARTILLERY *and* STORES *necessary for a field equipage.*

THE estimates of an equipage either for the field or a siege, which have hitherto been made, are intermixed with so many other things, which the duty of an artillery officer has no immediate connection with, that it is scarcely possible to distinguish the one from the other. It is true that these things are necessary in the field, but then I would mention them in separate articles, and let the artificers determine what tools and materials each branch wants. We shall therefore compute here the quantity of artillery, ammunition, and stores, leaving the determination of the rest to those who are employed to do this business.

The

The quantity of artillery required upon different occasions depends on so many circumstances, that nothing precisely can be determined; not only the strength of the army is to be considered, but likewise the particular circumstances in regard to the action they are about; the nature and situation of the country; the strength of places, whether sea port towns or inland, great or small, strong or weakly garrisoned; their quantities of guns and stores; in general, every thing that makes it necessary to have more or less artillery must enter into the determination before a resolution can be taken. It was esteemed formerly, that an army of 50000 men should have 50 pieces of cannon, with all their appurtenances, and so more or less in proportion; but since that time a much greater number has been used, especially now, when two field pieces are allotted to every battalion, besides a separate equipage, to be employed upon particular occasions.

The manner of computing the quantity of powder and shot for an army.

It will be necessary that young officers should know the manner and principles upon which the quantity of stores for an army are determined; for which reason we shall begin with the common light field pieces.

The 3, 6, and 12 pounders light, are commonly charged with a quarter of the shot's weight; therefore a 3 pounder requires for 100 rounds 75 pounds of powder, and 300 pounds of shot neat weight.

A 6 pounder for the same number of rounds, 150 pounds of powder, and 600 pounds of shot. The 12 pounder for the same number, 300 pounds of powder, and 1200 pounds of shot. The 24 light pounder is loaded with 5 pounds, therefore requires 500 pounds of powder for 100 rounds, and 2400 pounds of shot. These four pieces, which are the only calibers used at

preſent in the field, require therefore 1025 pounds of powder, and 4500 pounds of ſhot for 100 rounds.

The long heavy pieces require a charge of one third of their ſhot's weight, and no more even for making a breach, as found by experience. Hence, a 3 pounder heavy requires 100 pounds of powder for 100 rounds; a 6 pounder 200; a 12 pounder 400; and a 24 pounder 800. Total 1500 pounds of powder, and the ſame number of ſhot as before.

The quantity of powder required for howitzes and mortars is uncertain; for it depends on the diſtances the ſhells are to be thrown.

Powder and ſhot for muſkets, carbines, and piſtols.

29 muſket bullets weigh 2 pounds; and hence 700 men, or a compleat battalion require $24\frac{4}{29}$ pounds of lead for one round, or 2407 pounds for 100 rounds; muſkets, carbines, and piſtols require a charge of powder for loading and priming, equal to half the weight of the bullets; therefore a battalion requires 1203 pounds of powder to fire 100 rounds.

20 bullets for carbines weigh a pound, whence 120 men, or a ſquadron of horſe require 600 pounds of ſhot for 100 rounds, and 300 pounds of powder. 34 bullets for piſtols weigh a pound; ſo that a ſquadron requires 176 pounds of lead, and 88 pounds of powder, for 50 rounds.

Now it the ſtrength of an army is known, as well as the number of rounds allowed them in a campaign, it will be very eaſy to know the quantity of powder and bullets that is required. There is ſcarcely more rounds allowed than what we have mentioned here, which ſeems to be quite ſufficient for the foot, eſpecially when it is conſidered, that perhaps one third of an army does not act in an engagement. As for the horſe there is more than what is neceſſary, ſince their action conſiſts chiefly with the ſword, whilſt they are on horſeback; but as the

the dragoons fight alſo on foot in a cloſe country full of hedges and ditches, where the horſes cannot paſs, they may be ranked with the foot.

It has been found by experience, that a man may raiſe a weight equal to his own, and that he may carry or draw about 50 pounds to a moderate diſtance; and it has been found, that one horſe can draw as much as ſeven men *; therefore a horſe will draw or carry 350 pounds, though it is commonly ſuppoſed, that a horſe can draw but 300 for a length of time; and it is upon this ſuppoſition that the number of horſes required in the artillery is computed. We have found likewiſe that ſix men will draw a light 6 pounder in the field backwards and forwards.

Number of horſes.

Before we can compute the number of horſes, it is neceſſary to know the weight of each piece; from whence it appears, that a 3 pounder requires but 1 horſe, a 6 pounder 2, a 12 pounder 3, and a 24 pounder 6, of the light ſort; and the heavy 3 pounder 4 horſes, the ſix 7, the twelve 10, and twenty four 17 or 18.

Therefore the number of horſes, for a ſet of light pieces is 12, and the number for a ſet of the heavy 38, which is above three times more than the former; and from thence one may imagine how much expence is ſaved by making uſe of theſe light pieces in a campaign in this article alone, beſides what is ſaved in metal, workmanſhip, and in men to manage them.

Light Pieces.

Caliber.	Weight.
3	2 : 2 12
6	4 : 3 10
12	8 : 3 8
24	16 : 3 13

Heavy.

Caliber.	Weight.
3	11 : 0 : 0
6	19 : 0 : 0
12	29 : 0 : 0
24	51 : 1 : 12

* *Belid. Hydraul.* vol. i. p. 44. art. 123.

It muſt be obſerved, that though horſes may draw ſuch a weight upon a common carriage, yet as thoſe of guns are ſo injudiciouſly contrived, and the draught ſo diſadvantageous, as we have ſhewn in the conſtruction of limbers, the 12 pounders and upwards require more horſes than what we have ſet down here. But to give ſome idea of the number of horſes required in the artillery, we ſhall ſet down here the number employed in the campaign of 1747, given to me by Colonel *Michelſon*, where the reader will find many articles that could not be known without experience; and from thence it may be gueſſed what would be neceſſary in ſieges.

Number of horſes uſed in the campaign of 1747.

Number		Each	Total
1	Kettle drum	4	4
2	Tumbrels	2	4
6	Twelve pounders	15	92
6	Nine pounders	11	66
14	Six pounders	7	98
26	Three pounders	4	104
2	Howitzes	5	10
20	Ammunition carts	3	60
2	Forge carts	2	4
30	Pontoons	7	210
3	Spare carriages for ditto	7	21
	Spare carriages for guns.		
1	Twelve pounder	7	7
1	Nine pounder	5	5
2	Six pounders	5	10
4	Three pounders	3	12
	Spare limbers.		
3	Twelve pounders	2	6

3 Nine

3 Nine pounders	2	6
2 Six pounders	1	2
3 Three pounders	1	3
Spare horses		20
Total number of horses		738

Baggage waggons for the officers.

	Waggons	Horses
Colonel	3	10
Comptroller	3	11
Major	2	7
4 Captains	4	16
5 Captain Lieutenants	5	15
16 Lieutenants and Col. clerk	6	18
Quartermaster	1	3
Surgeon	1	3
Paymaster	1	3
Paymaster's assistant and surgeon's mate	1	3
Chaplain and Compt. clerk	1	3
Commissary and waggon master	1	4
2 Assistants to ditto	1	3
2 Commissaries of stores	2	6
2 Clerks of stores	1	3
Conductors of stores	2	6
Bridgemaster	1	3
16 Engineers	12	36
5 Company's baggage	5	15
Contractors, artificers	6	18
Total	59	186

Waggons for stores.

Flag-waggon for the army and artillery guard	1	3

	Waggons	Horses
Picket and Provoſt — —	1 —	3
12 Pounders ſtores —	9 —	27
9 Pounders ditto — —	7 —	21
6 Pounders ditto — —	12 —	36
3 Pounders ditto — —	10 —	30
40 Rounds for Howitzes and Petards — —	4 —	12
50 Rounds Royal, &c. —	2 —	6
Ammunition for 35,000 men —	122 —	360
Intrenching tools — —	24 —	72
Laboratory ſtores — —	2 —	6
Gin waggon — —	1 —	3
Small ſtores, artificers tools —	20 —	60
Spare waggons — —	10 —	30
Total — —	225 —	675
From which is to be deducted		
20 Ammunition carriages —	10 —	30
For three pair of boxes —	12 —	36
Total — — —	22 —	66
Remains — —	203 —	609
Add baggage waggons —	59 —	186
Horſes for the guns — —		738
Sum total — —	262 —	1533

N. B. Several remarks are to be made on this account, in order to underſtand it rightly. The flag gun, which is a 12 pounder, had 17 horſes to draw it, although the reſt had but 15, which makes up the number 92 horſes for the ſix 12 pounders: with regard to the waggons, ſome were drawn by three horſes, and others by four; thus the comptroller had two waggons drawn by four horſes, and one by three. As to the ammunition carriages which were deducted, the colonel forgot on what account; all he remembers is, that they were either

either detached, or were not brought into the field that campaign; but as to the number of horſes employed, the account is right. Hence it appears, that there are many things neceſſary, which can no otherwiſe be known than by practice. We ſhall therefore add an account of the ſtores carried into the field the ſame year, where the reader will find how neceſſary it is to ſtudy that branch of buſineſs, if he intends to be a compleat artilleriſt.

Stores for the army, in 1747, alphabetical.

Aprons of lead			66
			Fore Hind
Axle-tree bound, ſpare	12 pounders		1 : 2
	9		1 : 2
	6		1 : 3
	3		2 : 4
For tumbrels, forge, &c.			3
Axes	felling		150
	pick		1495
Bags for	ſhot, flints		634
	ſponges		60
Barrels, budge			20
Banners for kettle drum			2
Bayonets			840
Barrows	wheel		50
	hand		50
Beds for	guns		12
	mortars		7
Bills, hand			1499
Bridles for kettle drum chariot			4
Bruſhes for harneſs to ditto			4
Buckets of leather			36
Carriages, travelling with limbers, compleat	12 pounders		7
	9		7
	6		23
	3		26
For 8 inch howitzes			2

For pontoons		33
Cartridges, flannel, fixed with grape	12 pounders	180
	9	192
	6	560
	3	1040
For howitzes		20
Ditto with round ſhot	12 pounders	30
	9	30
	6	70
	3	130
Empty paper cartridges	12 pounders	650
	9	650
	6	1550
	3	2220
Cartridges for muſkets		76152
Carts	ammunition	20
	forge	2
Candles	wax lb.	50
	tallow	80
Crows, iron		15
Canteens		230
Caps for mortars		6
Cartouch boxes		1000
Chariot for kettle drum		1
Cloths	hair	24
	oil	2
Clouts, ſpare	body	104
	linch	100
Chains, draught	12 pounders	7
	9	7
	6	16
Chains for howitzes		2
Coals	char. buſhels	12
	ſea, ſacks	22
Colours, quarter, with ſtaves		40
Cord, whip lb.		1

Coins

Coins	12 pounders	14
	9	14
	6	32
	3	34
	for howitzes	4
Couples for chain traces		500
Deals	whole	40
	ſlit	40
Drums, kettle, pair		1
Eſſes for draught chains		60
Flags	union	2
	red	1
Flambeaux, doz.		5
Flints	muſket	198510
	carbine	5720
	piſtol	10000
Formers for	12 pounders	1
	9	1
	6	1
	3	1
	muſkets	180
Forelock keys		423
Glue, lb.		6
Greaſe, firkins		33
Gins compleat		2
Hammers	claw	4
	ſmall	4
Hand ſpikes		148
Hand ſcrews		9
Hand grenades	fixed	2000
	empty	4000
Horſe harneſs	thill	95
	traces	404
	wanties	95
	bit halter	484
Harneſs for	kettle drum chariot, 4 to a ſet	1
	men, 12 to a ſet	40
Hatchets, hand		1030

Haverſacks		216
Helves, ſpare, for pickaxes		100
Heads, ſpare, for kettle drums		2
Hemp rubbiſh, lb.		6
Hides tanned		42
Hooks, pairs	car	4
	ſling	4
Hoops, hazle		1000
Horns, powder		39
Howitzes		2
Irons	flat	5:0:12
	hoop	0
	rod	2:2: 6
	ſquare	0:3:30
Iron priming, 4 to a ſet		60
Irons for marking horſes		3
Kettles, copper, with covers		40
Keys, ſpring		50
Ladles with ſtaves	12 pounders	6
	9	6
	6	20
	3	26
Ladles for 8 inch howitz		2
Lanterns	dark	6
	Muſcovy	6
	ordinary	6
	tin	12
Limbers ſpare	12 pounders	1
	9	1
	6	2
	3	3
	for howitzes	1
Links, dozens		12
Lines, Hamborough, lb.		60
Lint ſtocks	with cocks	60
	without	50
Locks, ſplinter, pad		80
Linch pins, pairs		56

Marlin

Marlin	tarred, ſheets	42
	white	20
Mauls, large wooden		4
Match		29 : 0 : 27
Meaſures for powder, copper, from 3 lb. to $\frac{1}{2}$ oz. from 8 oz. to $\frac{1}{4}$ ſets	12 pounders	1
	9	1
	6	1
	3	1
Meaſure for coals 1 buſhel		1
Medicines, cheſts		2
Mortars, coehorn		6
Moulds for	carbines	2
	piſtols	2
	muſkets	4
	ditto	6
Muſkets		925
Nails	40	20000
	30	2800
	20	6000
	10	5000
	6	4000
	4	4000.
	clout	3500
	copper	300
	dog	500
	ſtreak	128
Ordnance, braſs	12 pounders	6
	9	6
	6	20
	3	26
Pannels for carrying mortars		6
Paper, fine, reams		2
Picket line, rope, 2 $\frac{1}{2}$ inch coils		5
Pickets, park, ſhod		60
Petards fixed		12
Pails, wooden		6
Pontoons		30

Powder,

Powder, corned, barrels		966
Rods for	muſket	680
	carbine	100
	piſtol	200
Rings for forelocks		100
Ropes, drag	12 pounders	7
	9	7
	6	23
	3	30
	for howitzes	2
Rope tarred, 2 ½ inch feet		30
Ropes, white, coils	5 inch	1
	4	1
	3 ½	1
	2	1
Saws croſs cut		6
Scales, braſs, pairs		1
Screws for guns	12 pounders	6
	9	6
	6	20
	3	26
Shells, empty	8 inch	199
	5. 5	294
Shells, filled	8	20
	5. 5	120
Sheep-ſkins		117
Shovels		1000
Shot, lead	muſket, tons	58 : 19 : 1
	carbine	0 : 11 : 2
	piſtol	0 : 10 : 0
Shot, round	12 pounders	593
	9	599
	6	1390
	3	2594
Shot, grape	12 pounders	90
	9	90
	6	70
	3	750

Slings

Slings for guns, pairs		7
Spikes for ditto		300
Spades		1934
Sponges with rammers	12 pounders	6
	9	6
	6	20
	3	26
Ditto for	howitzes	2
	mortars	6
Staves for	flags	3
	ladles	50
Shot iron for grape		8000
Steel		1 : 2 : 16
Sticks for kettle drums, pairs		3
Stilliard with weight to weigh hundreds		1
Swing trees, pairs	12 pounders	7
	9	7
	6	14
	howitz	2
Tampeons, with collars	12 pounders	6
	9	6
	6	20
	3	26
	howitz	2
Tilts, wadmill		22
Tarpaulins		70
Tents	field officers	2
	captains	7
	ſubaltern	7
	horſemens	28
	French	140
	bell	13
	laboratory	2
Thread	fine	1
	pack, lb.	30

Tools

Tools for artificers	carpenters cheſts	3
	wheelers	3
	ſmiths	3
	tinmens	2
	collar-makers	2
	coopers	2
	miners	2
Tin tubes	12 pounders	214
	9	214
	6	500
	3	1300
Tumbrels		3
Twine, lb.		20
Tug-pins, ſpare, pairs		24
		Fore Hd.
Wheels, ſpare, pairs	12 pounders	1 : 2
	9	1 : 2
	6	1 : 2
	3	2 : 3
Ditto for	howitz	1 : 2
	forge or tumbrel	2
	ammunition waggons	2
Wad-hooks	12 pounders	6
	9	6
	6	20
	3	26
Waſhers, pairs		43
Weights, braſs		1
Whips for drivers		3

Laboratory ſtores.

Fixed fuſes	7 ¾ inches	250
	5 ½	3354
	hand	3000
Iron drills for fuſes	7 ¾	4
	5 ½	6
	hand	6

Hand

Hand mallets of sorts for ditto —	16
Small copper ladles { 7 ¾ — —	4
Small copper ladles { 5 ½ — —	6
Small copper ladles { hand — —	6
Setters of wood for fuses — — —	4
Mealed powder, lb. — — —	210
Sulphur sublimate, lb. — —	74
Composition for fuses, lb. — — —	25
Quick match, lb. — — —	62
Port fires — — —	1116
Pockets of 2 lb. for signals — —	12
Rods for ditto — — —	12
Canvas, ells — —	60
Cotton wick, lb. — — —	40
Spirits of wine, gallon — —	1
Cutting knives — — —	10
Rasps with handles — — —	6
Scissars, pairs — — —	4
Pincers for fuses — — —	6
Small hand-saws — — —	6
Copper { salting-boxes — — —	2
Copper { funnels for shells — — —	2
Melting ladles of sorts — — —	4
Mealing table — — —	1
Trusses for ditto — — —	2
Rubbers for ditto — — —	2
Hand-brushes — — —	4
Sieves with tops and bottoms lawn —	2
Drawing knives — — —	3
Quadrants — — —	2
Machine to draw fuses — — —	1
Kitt { lb. — — —	45
Kitt { kettle — — —	1
Laboratory chest, with padlock and key —	1

I had this account from the Tower, but could have wished that the particulars of each sort had been in separate articles, which we might have done, were it

not

not that we thought the reader would be pleaſed to ſee the order and the particulars as cuſtomary.

Order of General BELFORD'*s march of the* ARTILLERY.

1. A guard of the army.

2. The company of miners, with their tumbrel of tools, drawn by 2 horſes.

3. The regiments of artillery front guard.

4. The kettle drums drawn by 4 horſes, and two trumpeters on horſeback.

5. The flag gun drawn by 17 horſes, and five 12 pounders more, by 15 horſes each.

6. Eleven waggons with ſtores for the ſaid guns, and one ſpare, by 3 horſes each.

7. Six 9 pounders drawn by 11 horſes each.

8. Nine waggons with ſtores for the ſaid guns, and one ſpare, by three horſes each.

9. Five long 6 pounders, by 7 horſes each.

10. Seven waggons with ſtores for ditto, and a ſpare one, drawn by 3 horſes each.

11. Five long 6 pounders, drawn by 7 horſes each.

12. Six waggons with ſtores for ditto, and a ſpare one, by 3 horſes each.

13. Four long 6 pounders, by 7 horſes each.

14. Five waggons with ſtores for ditto, and a ſpare one, by 3 horſes each.

15. Two howitzes, by 5 horſes each.

16. Four waggons with ſtores for ditto, by 3 horſes.

17. Six ſhort 6 pounders, by 2 horſes each.

18. Three waggons with ſtores for ditto, by 3 horſes each.

19. Six royals, with their ſtores in four waggons, by 3 horſes each.

20. One 12 pounder carriage, by 7 horſes; one 9 pounder carriage, by 5; one long 6 pounder carriage, by 5; two ſhort, by 2; one ſhort and one long limbers, by 1 horſe; and two forges, by 2 each.

21. Twenty

21. Twenty ammunition carts, by 3 horſes each.

22. Nineteen waggons, with muſket cartridges, and one ſpare, by 3 horſes each.

23. Thirty waggons with powder, and one ſpare, by 3 horſes each.

24. Thirty waggons with muſket ſhot, and one ſpare, by 3 horſes each.

25. Twenty-five waggons with intrenching tools, and one ſpare, by 3 horſes each.

26. Twenty-five waggons with ſmall ſtores, and one ſpare, by 3 each.

27. Six waggons for artificers, with 4 ſpare, each by 3.

28. Thirty-two baggage waggons, 9 by 4 horſes, and 23 by 3.

29. Thirty pontoons and 3 ſpare carriages, each by 7.

30. The artillery rear guard.

31. The rear guard from the army.

It muſt be obſerved, that there are parties of gunners and matroſſes marching with the guns; there are likewiſe ſome parties of pioneers interſperſed here and there to mend the roads, when they are ſpoiled by the fore carriages.

There was then 1415 horſes employed this campaign, 32 guns, 2 howitzes, 6 ſmall mortars, 244 waggons and carts, and laſtly, 30 pontoons; 20 of theſe laſt are eſteemed ſufficient for any part of *Flanders*, becauſe there is no river in this country that requires more to make a bridge over it.

The *French* march their artillery much in the ſame manner, but divide it into brigades, each of which is commanded by its proper officers, has a detachment of pioners to aſſiſt in bad roads, as likewiſe a guard of gunners and matroſſes: the firſt brigade conſiſts always of ſome light pieces, followed by their proper ammunition, and preceded by a waggon loaded with tools

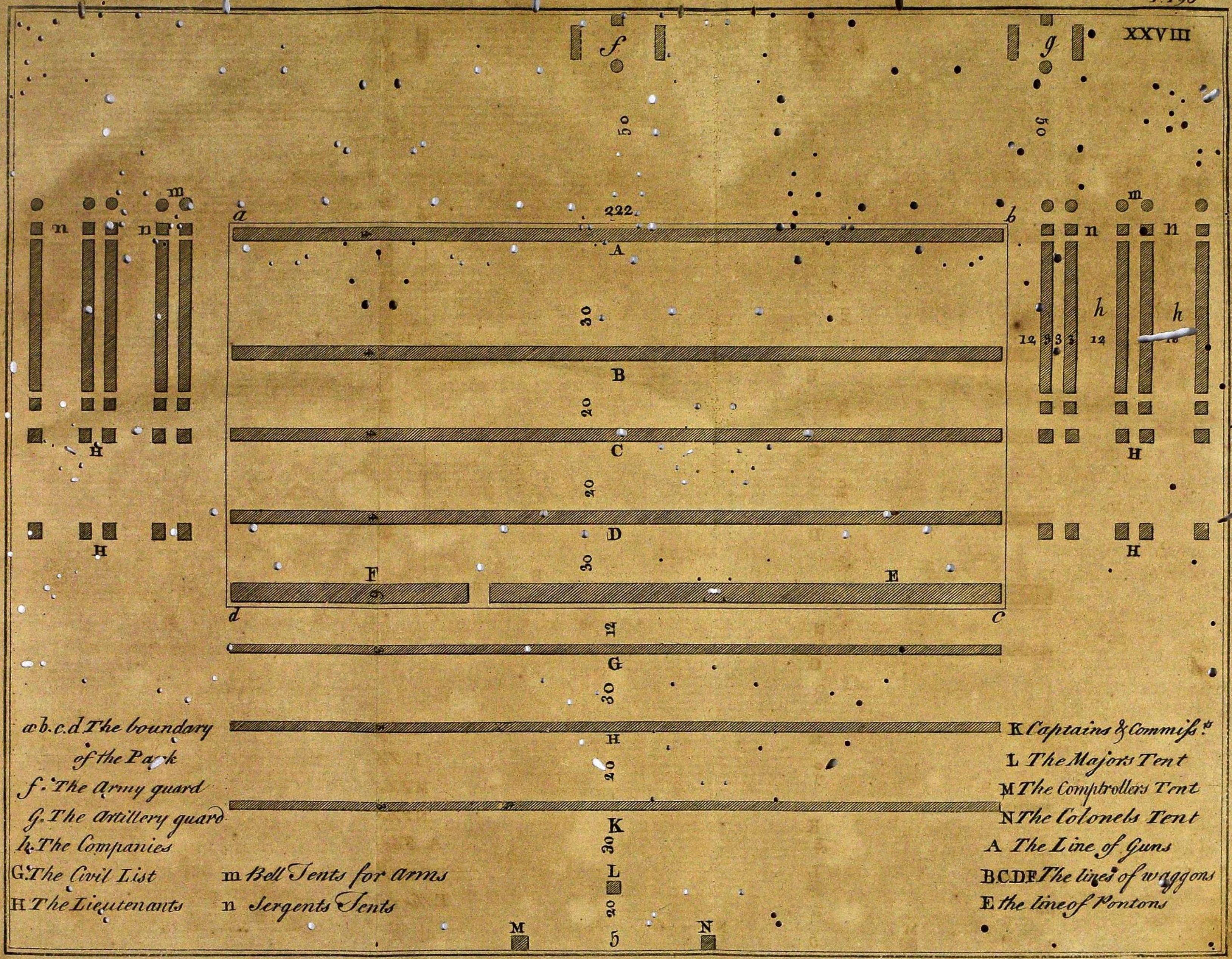
in order to make and clear the roads, if there is any occaſion; a gin follows each diviſion loaded upon a ſpare carriage; the next brigade follows in the ſame order, and preceded with a carriage loaded with tools, with a detachment of pioneers.

The middle brigade conſiſts of the heavieſt pieces, and is called the park brigade; and as the others are only followed by ſo much ammunition as is ſufficient upon a ſudden occaſion, the reſt follow the park brigade. After this comes the baggage, and then the pontoons, with this reſerve, that if the army is to croſs a river, then as many pontoons march at the head as are ſufficient to make a bridge.

N. B. The front guns ſhould always carry 15 or 20 rounds in their lockers, to be ready to fire upon any ſudden occaſion, the pieces ſhould be loaded, and the gunners have their matches lighted during the march.

The detachments which march at the heads of the brigades, are to take care that the army baggage does not croſs the artillery, and the pioneers, if any carriage is overſet or ſtopt, to aſſiſt it; and in that caſe, word is given to the brigades before to ſtop, till all are ready to march, and when there is any ſtopping behind, thoſe before draw up cloſe at the ſide of each other, till the reſt come up, and then march on a common pace. Regularity and order ſhould be obſerved by all means to prevent confuſion, which is almoſt impoſſible where there are ſo many carriages.

It muſt be obſerved, that the heavy 24 pounders, or upwards, and the mortars, muſt be carried upon block carriages; for they would require too many horſes to draw them upon their own. Thoſe who want a farther inſight into theſe affairs, may conſult *S. Remy*'s Treatiſe of Artillery, where they will find every thing explained in a very ample manner; and which we could not do in


XXVIII
a.b.c.d The boundary of the Park
f. The Army guard
g. The Artillery guard
h. The Companies
G. The Civil List
H The Lieutenants
m Bell Tents for arms
n Sergents Tents
K Captains & Commiss.rs
L The Majors Tent
M The Comptrollers Tent
N The Colonels Tent
A The Line of Guns
B.C.D.F. The lines of waggons
E the line of Pontons

ſo ſmall a work as this. We intended to treat of the moſt eſſential part only, and ſuch as ſhould be known to moſt artillery officers, who expect to have a command.

To form a park of ARTILLERY. Plate XXVIII.

The artillery is generally placed about 300 paces before the middle of the firſt line of the army, upon ſome riſing ground, except a more convenient ſpot of ground happens to be before ſome wing; but let the ſituation be where it will, the manner of forming the park is the ſame, except that ſome artillery officers differ in the diſpoſition of the carriages. Some place all the cannon and mortars in the front, with their ſpare carriages; others are for dividing the equipage into brigades, and place the firſt in the front line, the ſecond into the next; and ſo on. But the beſt approved method is to divide the artillery into brigades, and to place the guns of the firſt to right of the front line, and their ammunition behind them in one or more lines; then thoſe of the ſecond brigade next to the firſt in the front, leaving five paces between them, and their ammunition behind them, as before; and continue placing all the reſt in the ſame order, the pontoons forming the laſt line. General *Belford*'s diſpoſition in the laſt war was:

The firſt line conſiſted of 32 guns mounted upon their carriages, ſeven ſpare carriages, 20 ammunition carts, and two howitzes; the guns pointing forwards.

The { ſecond line of 50 waggons.
third of 52 waggons.
fourth of 50 waggons.
fifth of 14 waggons, 30 pontoons, and three }

ſpare carriages. Each carriage takes up two paces or yards, and they are placed at the ſame diſtance in the ſame line; the ſecond line is 30 paces behind the firſt; the two next 20 from each other; and the laſt 30 again.

The artillery companies and miners are half incamped to the right, and the other half to the left of the park, in the usual manner, with some of the lieutenants in the rear of them.

In the rear of, and 12 paces from, the park are incamped the civil list all in one line; behind these, and at 30 paces distant, is a line of the remaining lieutenants; and behind these the captains and commissaries.

Opposite to the middle, and 30 paces behind the captain's line, is the major's tent; and behind this, at 20 paces, the colonel's to the right, and the comptroller's to the left.

Opposite to the middle, and 50 paces before the park, is placed the army guard; and opposite to the right wing, the artillery guard at the same distance.

The *French* method is; the cart loaded with tools, which marches at the head, is placed to the right of the first line; next to that the guns of the first brigade, which commonly consists of 4 or 6 small pieces, with a spare carriage to the left of them; the ammunition carriages of this brigade are placed behind in one or more lines, at 30 paces distant from line to line. After this, the second and succeeding brigades are placed in the same manner, leaving five paces interval between the brigades: they continue thus to place all the guns, with their spare carriages, in the front line; the last line is made by the pontoons and other carriages.

S. Remy says, that seven pontoons will be sufficient to make a bridge over any river in *Flanders*; but I believe he did not mean the *Scheld* or the *Maese*, which seem to require more. It is however certain, that they carry no more than 20 pontoons and two spare carriages into the field; which is one third less than we do.

In the middle of the front two light pieces are advanced at a distance of 20 paces, loaded with powder for the alarm guns ready to be fired when required.

To the right of the park are placed the artificers, with their tools, materials, and baggage, in a line from the

the front to the rear. To the left of the park, the commiſſaries aud their baggage; to the right of the artificers is incamped the firſt battalion of artillery, with their baggage and officers behind them in the uſual manner; and to the left of the commiſſaries, the ſecond battalion in the ſame manner as the firſt.

The horſes of the equipage are placed behind the firſt battalion, except thoſe of the picket, in the rear of the park.

What has been ſaid here is ſufficient to give a clear idea of a park for a field equipage to a young officer; but, with regard to one before a town beſieged, we ſhall refer the reader to the works of *French* authors, who have wrote largely upon it.

REMARKS.

To determine the quantity of guns, ammunition, ſtores, and every thing elſe neceſſary in the field or a ſiege, ſo as to have enough, and no more, requires more knowledge and experience than can be found in one man. The *French* have a ſet of officers, whoſe buſineſs it is to manage theſe affairs, and who are gradually initiated into it. It is from their works that moſt nations of *Europe* copy the quantities of ſtores wanted upon different occaſions. As our commiſſaries of ſtores are taken into the ſervice when they are wanted, and diſcharged again ſo ſoon as the war is over, it is impoſſible we ſhould ever have any one capable of making a proper eſtimate, unleſs the artillery officers would undertake that branch of buſineſs, which they conceive not to be their duty; but as they have more opportunities to be informed than any body elſe, and if any material article ſhould be wanted in an action they may be blamed, I imagine it would conduce much to their honour, and be at the ſame time for the public advantage, if they did. It was to aſſiſt them as much as in my power, that this work was wrote, which, by the help of expe-

rience, will, I hope, be ſufficient to make an eſtimate of the moſt material articles, leaving the reſt to the artificers to determine the quantities of materials and tools they want, or to thoſe who have been employed in that buſineſs.

Before we leave this ſubject, we muſt take notice of ſome defects in our ſtore carriages. As there are a great number of them not ſo well contrived as they ſhould be, it not only increaſes uſeleſs expences, but likewiſe cauſes more trouble in the marching, and ſhould be avoided. Firſt, as our powder carts hold no more than four barrels, and a great quantity is required in all expeditions, they are not ſufficient; for which reaſon there ſhould be powder waggons to hold twelve barrels each. It is true, that the powder carts carry leaden bullets and flints at the ſame time; and are therefore more convenient to follow the battalions; but the reſt ſhould be carried in much larger quantities. The ſame thing may be obſerved in reſpect to all other carts; though they may be uſeful upon ſome particular occaſions, yet they ſhould not be uſed in carrying great quantities of any kind, for the whole weight lying upon one axle-tree, muſt require more horſes to draw a weight, than when the ſame weight lies upon two. This every carrier muſt know; and therefore no more carts ſhould be uſed than are neceſſary.

As to the pontoon carriages, we have obſerved, after their conſtruction, how unſkilfully they were made, the pontoons being twenty feet long, which is longer than any waggon, and yet are ſupported only by one axle-tree; therefore the ſhaft-horſe is hardly able to ſupport the weight laid upon it. As a pontoon cannot weigh above 1200 lb. with all its appurtenances, it appears very extraordinary, that there ſhould be ſeven horſes required to draw each, it can certainly be owing to no other cauſe than to the ill contrivance of the carriage: I would therefore make them with four wheels, and the fore ones but low, with a high bolſter, that it may

may turn with more eaſe in narrow roads; this being done, I am perſuaded, that four horſes would be ſufficient to draw them. The travelling forge is no better contrived than the pontoon carriages; for, when it is to be uſed, it is ſupported before by two props fixed to the ſhafts, which, by the leaſt accident, may give way, and down it goes. Nothing but the fondneſs for carts can excuſe ſuch a contrivance. [This has been remedied in ſome reſpect, as we have obſerved before.]

All carriages made uſe of in the artillery have ſhafts; and, to prevent the great length of thoſe that require a great number of horſes, the rule is to draw by pairs a-breaſt, which is an abſurdity no where elſe to be met with; for when the road is frequented by carriages drawn by two horſes a-breaſt, there is always a ridge in the middle, which the ſhaft-horſe, endeavouring to avoid, treads on one ſide, whereby the wheels catch againſt the ruts, and ſtop the carriage; and when the fore horſes bring them back, he treads on the other ſide, where the ſame happens again; ſo that the ſhaft-horſe, inſtead of being uſeful any other ways than to ſupport the ſhafts, becomes a hindrance to the reſt: on the contrary, if the road is frequented by carriages drawn by horſes all in a ſtring, the fore-horſes muſt either tread in the ruts, or elſe the road muſt be quartered; and in that caſe the ſhaft-horſe muſt walk in the rut; conſequently, in all roads, except they are paved, either the ſhaft or the fore-horſes muſt draw with all the diſadvantages poſſible. This has never been taken notice of by any of thoſe who have the direction of theſe affairs, though no carriages require more perfection in their conſtruction than theſe, on account of the great number wanting, and the heavy burthen that moſt of them are obliged to carry.

This defect may be remedied by making two pair of ſhafts in all four-wheel carriages, in the ſame manner as is done in waggons that carry great loads.

Laboratory Works.

My design is not to give here any more than what is just necessary for the young artillerist to know in the course of his duty, referring that part which regards the fire-works made for rejoicing to the excellent Treatise on Artificial Fireworks, wrote by *Robert Jones*, Lieutenant in the Artillery, who gives all that can be said on that subject, and has himself practised every part of it. Printed for *J. Millan.*

Grapeshot.

The number of shot in a grape varies according to the service or size of the guns; in sea-service 9 is always the number; but by land it is increased to any number or size; from an ounce and a quarter in weight, to 3 or 4 pounds. It has not as yet been determined, that I know of, what number and size answers best in practice; which I think ought to be tried: for it is well known, that they often scatter so much, that only a small number take place. It would not be a useless experiment, to try at what distance they would do most execution, and what is the best charge of powder. In sea service, the bottoms and pins are made of iron, whereas those used by land are of wood; for what reason this distinction is made, I cannot tell, unless that these iron bottoms are supposed to destroy the riggings of ships more than the wooden would do.

To make grapeshot, a bag of coarse cloth is made just to hold the bottom which is put into it; then as many shot as the grape is to contain; and with a strong packthread they are quilted to keep the shot from moving: and when they are finished are put into boxes for carriage, to be transported where-ever it is necessary. When the shot are very small, they are put into tin boxes that just fit the bore of the gun. Leaden bullets are likewise used

used in the same manner. It must be observed, that whatever number or sizes of the shots are used, they must weigh with their bottoms and pins nearly as much as the shot of the piece.

CARTRIDGES.

The loading and firing guns with cartridges is done much sooner, and less liable to accidents, than with loose powder. They are made of various substances, such as paper, flannel, parchment, and bladders. When they are made of paper, the bottoms remain in the piece, and accumulate so much, that the priming cannot reach the powder; and therefore they must be drawn from time to time, which retards the service. They have another inconveniency, which is, they retain the fire; and, if particular care is not taken in spunging the piece, they will set fire to the next cartridge, and the gunner that puts it into the piece will be in danger of losing a hand or arm, as has sometimes happened. When they are made of parchment or bladders, the fire shrivels them up, whereby they enter into the vent, and become so hard, that the priming iron cannot remove them so as to clear the vent. Nothing has been found hitherto to answer better than flannel, and is the only thing used at present, because it does not keep fire, and therefore not liable to accidents in the loading; but as the dust of powder passes through them, a parchment cap is made to cover them, which is taken off before this is put into the piece.

The best way of making flannel cartridges is, is my opinion, to boil the flannel in size; this will prevent the dust of the powder from passing through them, and renders them stiff, and more manageable; for without this precaution they are so pliable, that when they are large, and contain much powder, they are very inconvenient in putting them into the piece. The *Saxon*, who introduced our present light field pieces, had a particular method

method of preparing cartridges, which was ſuch, that when laid into the fire they would not burn; and yet, by dipping them into water before they were put into the piece, would take fire as quick as powder; but how he did it nobody could tell; for he would not part with his ſecret.

In quick firing the ſhot is fixed to the cartridge by means of a wooden bottom, hollowed on one ſide ſo as to receive nearly half the ſhot, which is faſtened to it by two ſmall ſlips of tin croſſing over the ſhot, and nailed to the bottom; and the cartridge is tied to the other end of this bottom. They are fixed likewiſe in the ſame manner to the bottoms of the grapeſhot, which are uſed in field pieces.

PORTFIRES.

Portfires are uſed ſometimes inſtead of matches, to ſet fire to powder or compoſitions; and are diſtinguiſhed into wet and dry. The compoſition of wet portfires is, ſaltpetre 4, ſulphur 1, and mealed powder 4; when the compoſition is well mixed and ſieved, it is to be moiſtened with a little linſeed oil, and well rubbed with the hands till all the oil is well mixed with the compoſition. The compoſition of dry portfire is, ſalpetre 4, ſulphur 1, mealed powder 2, and antimony 1. Theſe compoſitions are drove into ſmall paper caſes, and ſo kept till they are uſed.

QUICKMATCH.

It is made with three cotton ſtrands drawn into length, and put into a kettle juſt covered with white wine vinegar, and then a quantity of ſaltpetre and mealed powder is put in it, and boiled till well mixed. Others put only ſaltpetre into the water. After that, it is taken out hot, and laid into a trough where ſome mealed powder, moiſtened with ſpirits of wine, is thoroughly wrought

wrought into the cotton, by rolling it backwards and forwards with the hands: when this is done, they are taken out separately, and drawn through mealed powder, then hung upon a line till dry.

Tubes *used in quick firing.*

These tubes are here made of tin: their diameter is two-tenths of an inch, which is so as just to enter into the vent of the piece; about 5 or 6 inches long, with a cap above, and cut slanting below in the form of a pen; and the point is strengthened with some solder, that it may pierce the cartridge. Through this tube is drawn a quickmatch, and the cap is filled with mealed powder moistened with spirits of wine. To prevent the mealed powder from falling out by carriage, a cap of paper is tied over it, which is taken off when used; but latterly this cap is made of flannel steeped in spirits of wine, and with saltpetre dissolved in it; and there is no occasion to take it off, since it takes fire as quick as loose powder.

An objection is made against these tubes, which is, that the tin is apt to spoil the quickmatch when they are kept for some time; and it is imagined, that salt water would soon corrode them, and therefore not proper to be used on board of ships; this however has not been tried as I know of. The *French* use a small reed, to which is fixed a wooden cap about two inches long; they are filled with mealed powder moistened with spirits of wine, and a small hole is made through them the size of a needle, through which the fire darts with great violence, and gives fire to the cartridge, which must be pierced beforehand with the priming iron. These tubes may be kept a great while without being spoiled; but the piercing the cartridge retards the quickness of firing. The forementioned *Saxon* made his of copper, tapering towards the end, so as to enter the vent about half an inch, which is made so far in the same form, and the rest

rest very narrow: they are filled in the same manner as the *French*, and when fired, the flame darted through the cartridge without being pierced.

Fuses *for shells and hand-grenades.*

The composition for fuses is saltpetre 3, sulphur 1, and mealed powder 3, 4, and sometimes 5, according as it is required to burn quicker. Fuzes are chiefly made of very dry beech-wood, and sometimes of horn-beam taken near the root; the upper part of that wood splits very easily. They are turned rough, and bored at first, and then kept for several years in a dry place: the diameter of the hole is about a quarter of an inch, a little more or less is of no consequence; the hole does not go quite through, leaving about a quarter of an inch at the bottom; and the head is made hollow in the form of a bowl. The composition is drove in with an iron driver, whose ends are capped with copper to prevent the composition from taking fire; and equally hard as possible; the last shovel-full being all mealed powder, and two strands of quick-match laid across each other being drove in with it, the ends of which are folded up into the bowl, and a cap of parchment tied over it till used. It will not be improper to observe, that, when shells are to be thrown at a small distance, the composition should be made quicker than when they are to be thrown at a greater; for, by cutting them so as to burn but a short time, they might not be long enough to be well fixed into the shell, by which the blast of the powder in the chamber would blow them out, without the shell being able to burst. It must likewise be observed, that the custom of fixing the shells at home is very bad; since it is not known how long they should burn; and if they do not burst as soon as they fall, the execution is but trifling. Another disadvantage attends this practice; when they are carried into a hot climate, the wood shrinks, though ever so dry before; and the fuzes loosen

so

so much, that they fall out in the flight of the shell before it falls to the ground.

When the fuses are to be drove, the lower end is cut off in a slope, so as the composition may give fire to the powder; and they must have such a length as to burst nearly as soon as the shell touches the ground. When the distance of the battery from the object is known, the time of the shell's flight may be computed nearly; which being known, the fuze may be cut accordingly, by burning two or three, and making use of a watch or a string by way of a pendulum.

Before shells are loaded, they must be well searched within and without by means of a copper grater, to see whether there are no holes or cavities in them; after that they are put into a tub of water, so as to cover them, with an empty fuse drove into them; and the mouth of a bellows, being introduced into the fuze, and worked, will cause bubbles in the water, if there are any holes in the shell, but if no bubbles appear, it is a sign the shell is sound and fit for service.

When they are loaded, care must be taken that they are very dry within; and if the spike which supports the corp when they are cast, and which remains in them, is not beat down, it must be done then, otherwise it would split the fuse. Then the powder is put into it with a funnel, and not quite filled, that the fuze may have room to enter, which fuse is pressed in at first by the hand as far as it will go, and then drove with a mallet as hard as possible, taking care however not to split it; for if the least crack was in it, the composition would give fire to the powder, and the shell would burst either in the mortar or in the air, and so do no execution.

It is a query how much powder is to be put into a shell, so as to make it burst in most pieces? It is agreed by most officers that they should not be quite filled; one that has taken most pains to find it out is of opinion that they

they ſhould be filled within one third part of what they can hold.

"Lieutenant *Pirle*, a very ingenious mechanic, loſt in the *Dodington* ſome years ago going to the *Eaſt Indies*, had found out a method, ſo that as ſoon as the ſhell touched the ground it burſted: but being too modeſt a man, had not the aſſurance to propoſe it to the maſter general of the ordnance, whereby the world was diprived of ſo uſeful an invention.

If the fuſes are to be kept for ſome time after they are drove, the top muſt be covered with a mixture of pitch 2, roſin 1, and bees wax 3, whereby no air can come to the compoſition; and it will keep as long as you pleaſe.

Carcasses.

None but round carcaſſes are uſed at preſent, the flight of the oblong are ſo uncertain, that they have been quite laid aſide. The compoſition is pitch 2, ſaltpetre 4, ſulphur 1, and corned powder 3. When the pitch is melted, the pot is taken off, and the ingredients well mixed put in; then the carcaſs is filled with as much as can be preſſed in.

Light Balls *to diſcover the enemy's works.*

There are various ſorts deſcribed by different authors. Some are made of tow dipped into a compoſition of ſulphur, pitch, roſin, and turpentine; and worked up all together into a ball. Others take a ball of ſtone or iron, which is covered with ſeveral coats of compoſition much like that before-mentioned, till of a proper ſize; and the laſt coat is to be of grained powder. But the beſt ſort, in my opinion, is to make a ſhell of paper the ſize of the mortar, and to fill it with a compoſition of an equal quantity of ſulphur, pitch, roſin, and mealed powder; which being well mixed, and put in warm, will give a clear fire, and burn a conſiderable time.

There

There are many more things used in the defence of a breach; such as sacks filled with powder, bottles, barrels, &c. but as the chief intent of all these is to set fire, and blow up the assailants, and which every military gentleman may easily execute, we shall say no more here about them; our design being only to instruct the young artillerist in the most essential parts of his business; and to make him master of these matters, he must work in the laboratory; for practice is the best master.

FIRESHIP, *how to prepare it.*

From the bulkhead at the forecastle to a bulkhead to be raised behind the main chains, on each side and across the ship at the bulkheads, is fixed close to the ship sides, a double row of troughs, two feet distance from each other, with cross troughs quite round, at about two feet and a half distance; which are mortised into the others. The cross troughs lead to the sides of the ship, to the barrels, and to the port-holes, to give fire both to the barrels and to the chambers, to blow open the ports; and the side-troughs serve to communicate the fire all along the ship and the cross troughs.

The timbers of which the troughs are made are about five inches square; the depths of the troughs half their thickness, and they are supported by cross pieces at every two or three yards, nailed to the timbers of the ship, and to the wood-work which incloses the fore and main masts, and takes in an oblong in the middle of the deck, extending to the outside of both the masts, and in breadth is near one half of the deck; and is what makes the carpenter's room for his stores. The decks and troughs are all well paved with melted rosin.

On each side of the ship are cut out six small port-holes, in size about 15 by 18 inches, the ports opening downwards, and are close caulked up: against each port is fixed an iron chamber, which, at the time of firing the ship, blows open the ports, and lets out the fire.

At

At the main and fore chains on each ſide is a wooden funnel fixed over a fire barrel, and comes through a ſcuttle in the deck up to the ſhrouds to give fire to them; and between them are cut two ſcuttles on each ſide the ſhip, which alſo ſerve to let out the fire. Both funnels and ſcuttles muſt be ſtopt with plugs, and have ſail-cloth or canvas nailed cloſe over them, to prevent any accident happening that way by fire to the combuſtibles below.

The port-hole, funnels, and ſcuttles, not only ſerve to give the fire a free paſſage to the outſide and upper parts of the ſhip, and its rigging, but alſo for the inward air, otherwiſe confined, to expland itſelf, and puſh through thoſe holes at the time of the combuſtibles being on fire, and prevent the blowing up the decks, which otherwiſe muſt of courſe happen from ſuch a ſudden and violent rarefaction of the air as will then be produced.

In the bulkhead behind on each ſide is cut a ſmall hole, large enough to receive a trough of the ſame ſize as the others; from which, to each ſide of the ſhip, lies a leading trough, one end coming through a ſally port cut through the ſhip's ſide; and the other, fixing into a communicating trough that lies along the bulkhead, from one ſide of the ſhip to the other, and being laid with quickmatch only, at the time of firing either of the leading troughs, communicates the fire in an inſtant to the contrary ſide of the ſhip, and both ſides burn together. The communicating trough, which is fixed to the bulkhead, and the leading troughs, are the ſame ſize as the others.

Manner of preparing STORES.

FIRE-BARRELS.

The form of the barrels ſhould be cylindric, both upon the account of that make anſwering better for filling

filling them with reeds, and for ſtowing them on board between the troughs; their inſide diameters are ſufficient, if about 21 inches, and their lengths 33. The bottom parts are firſt filled with ſhort double-dipt reeds ſet on end, and the remainder with fire-barrel compoſition well mixed and melted, and then poured over them.

There are 5 holes of $\frac{3}{4}$ inches diameter, and 3 inches deep, made with a drift of that ſize in the top of the compoſition while it is warm; one in the center, and the other four at equal diſtances round the ſides of the barrel. When the compoſition is cold and hard, the barrel is primed by well driving thoſe holes full of fuze compoſition to within an inch of the top; then fixing in each hole a ſtrand of quickmatch twice doubled, and in the center hole two ſtrands the whole length; all which muſt be well ſet or drove in with mealed powder; then lay the quickmatch all within the barrel, and cover the top of it with a dipt curtain, faſtened on with a hoop to ſlip over the head, and nailed on.

The barrels ſhould be made very ſtrong, not only to ſupport the weight of the compoſition before firing, in removing and carrying them about, but to keep them together at the time they are burning; for if the ſtaves are too ſlight and thin, and ſhould burn too ſoon, ſo as to give way, the remaining compoſition would be apt to ſeparate, and tumble upon the deck, which would deſtroy the deſigned effect of the barrel, which is to carry the fire aloft.

Iron Chambers.

They are 10 inches long, and 3.5 in diameter; and breeched againſt a piece of wood fixed acroſs the portholes, and let into another lying a little higher; when loaded they are filled almoſt full of corned powder, and have a wooden tompion well drove into their muzzles; are primed with a ſmall piece of quickmatch thruſt

 through

through their vents into the powder, with a part of it hanging out; and when the ship is fired, they blow open the ports; which either fall downwards, or are carried away, and so give vent for the fire out of the sides of the ship.

Curtains.

Are made of barras about ¾ of a yard wide, and one yard in length; when they are dipped, two men with each a fork (or a shaft of the same size, with one prong in each if made on purpose) must run each of their prongs through a corner of the curtain at the same end; then dip them into a large kettle of composition well melted; and when well dipped, and the curtain extended to its full breadth, whip it between two sticks of about 5.5 feet long, and 1.5 inches square, held close by two other men to take off the superfluous composition hanging to it; then immediately sprinkle saw-dust on both sides to prevent its sticking, and the curtain is finished.

N. B. A copper fixed with a furnace is much better than a kettle that is not fixed, because it must be taken off from the fire for every dipping, to prevent the stripped off composition from falling into it, which would unavoidably give fire to the whole; and renders the use of a kettle tedious that way.

Reeds.

Are made up in small bundles of about 12 inches in circumference, cut even at both ends, and tied with two bands each; the longest sort is 4 feet, and the shortest 2.5; which are all the lengths that are used. One part of them are single dipped, only at one end; the rest are double dipped, that is, at both ends. In dipping, they must be put about 7 or 8 inches deep into a copper or kettle of melted composition; and when drained a little

little over it, to carry off the superfluous composition, sprinkle them over a tanned hide with pulverised sulphur, at some distance from the copper.

Bavins.

Are made of birch, heath, or other sort of brush-wood, that is both quickly fired and tough; in length 2.5 or 3 feet, the bush-ends all laid one way; and the other ends tied with two bands each. They are dipped and sprinkled with sulphur the same as reeds, only that the bush-ends alone are dipped, and should be a little closed together by hand as soon as done, before they are sprinkled, to keep them more close, in order to give a stronger fire, and to keep the branches from breaking off in shifting and handling them.

Disposition *of the* Stores *on board, when laid for firing.*

The fire barrels are placed under the funnels and scuttles, one to each; and are fixed between the cross troughs leading to the sides of the ship, and lashed to them, and well cleeted to the deck. Those at the funnels give fire to the main and fore shrouds; the rest rises over the deck through the scuttles. The plugs must be taken out of the funnels and scuttles before the ship is fired, and the curtains covering the fire-barrels cut open and rolled back, the quickmatch spread, and the top of the barrels well salted with priming composition. The curtains are nailed to the beams of the upper deck, hanging down over the troughs, bavins, and reeds.

The priming composition; a part of it is laid along the troughs, and the rest, after laying of the reeds and bavins, is regularly strewed over all. The short reeds double dipped, with some of the single dipped, are laid along both the sides and cross troughs, and communicate

the fire both to the barrels and chambers. The reſt of the ſingle dipped reeds and bavins are ſet about the fire-barrels, and to the ſides of the ſhip; and ſome flung upon the deck.

The quickmatch is laid two or three ſtrands thick upon the reeds in the troughs, and about the fire barrels and chambers, to communicate a general fire at once. The reeds in the troughs with the quickmatch are laſhed on, to prevent their falling out by the rolling of the ſhip.

The leading troughs are both laid with 4 or 5 ſtrands of quickmatch; as is likewiſe the communicating trough, that, by firing either of the leading troughs, the communicating trough may carry the fire to the other ſide of the ſhip; which then runs along the troughs by the quickmatch on both ſides, and give fire to the whole in an inſtant.

The Composition *made uſe of for* Curtains, Reeds, *and* Bavins, *are all the ſame*, viz.

Pitch	14	
Sulphur	7	*N. B.* For want of tar, take 3 lb. of tallow.
Roſin	7	
Tallow	2	
Tar	1	

Fire-Barrel Composition *for one* Barrel.

Corned powder lb. — — —	120
Pitch — — — —	60
Tallow — — — —	10

Divide the compoſition into five pots; the pitch and tallow muſt be firſt thoroughly melted. Tallow well the outſide of the pot to take off the heat; and then put in the powder by ſmall quantities, ſtirring it well about.

Priming

Priming Composition *for one* Barrel.

Corn powder lb.	100
Petre	50
Sulphur	40
Rosin	6
Oil, pints	3

Take 20 lb. of powder, which mix well with the petre, sulphur, and rosin, work them well together, breaking it well in working; then put the rest of the powder in by degrees, and work it altogether: spread it in a trough, and through a hair sieve run 3 pints of oil all over it; then work it well together, and run it through a cane sieve.

N. B. In the following estimate for the quantity of stores requisite, the reeds for the barrels are not included; it will take 100 short double dipped more than these specified; but their value is included in the article of barrels.

Stores *for a* Fireship *of* 150 *tons.*

	Numb.	Value. *l.* : *s.* : *d.*
Fire-barrels	8	80 : 0 : 0
Iron chambers	12	12 : 0 : 0
Priming composition barrels	3½	21 : 0 : 0
Quickmatch barrels	1	3 : 0 : 0
Curtains dipped	30	3 : 0 : 0
Long reeds single dipped	150	10 : 15 : 0
Short reeds double dipped	75	2 : 18 : 9
Short reeds single dipped	75	1 : 17 : 6
Bavins single dipped	209	10 : 0 : 0
		144 : 11 : 3

Quantity

Quantity of COMPOSITION *for preparing the* STORES *of a* FIRESHIP.

	pe-tre.	ſulp	corn pow.	pitch	ro-ſin	tal-low	tar	oil pts.
For 8 barrels — —	0	0	960	480	0	80	0	0
For 3.5 barrels of priming compoſition — —	175	140	350	0	21	0	0	11
For the curtains, bavins, and reeds for the ſhip, and ſulphur for ſalting them — —	0	200	0	350	175	50	25	0
Total —	175	340	1310	830	196	130	25	11

Total weight of the compoſition 3017 equal to C. 26 : 3 : 2.

Compoſition allowed for the reeds for the barrels one fifth of the whole of the laſt article, which is equal to 160 lb. and makes the whole 3177 pounds, or C. 28 : 1 : 13.

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F I N I S.

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